The AMSAT® Journal

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# RUDAK-U Digital Communications System to Fly on P3D

*by Lyle Johnson, WA7GXD, for the RUDAK-U team*

RUDAK-U is a digital communications system being designed for YOU! Currently slated to fly aboard the International Phase 3 D Satellite (P3D) being built by AMSAT organizations worldwide, RUDAK-U will bring real-time digital communications with global coverage.

Presently, your packet traffic is typically handled on VHF/UHF channels at 1200 bps or 9600 bps data rates. The station you directly communicate with is usually less than 25 miles (40 km) away. Most of your traffic is in the form of electronic mail, bulletins and programs or data files.

You've been conditioned to believe that packet is for non-real-time communications, and you've exploited this limitation. Some of you have tried to use packet for keyboard-to-keyboard QSOs and have had the local "experts" tell you are clogging up important file transfer channels, and that packet isn't intended for such communications.

Existing packet satellites have been optimized to exploit their low earth orbits (LEO) and are, in effect, flying mailboxes.

Well, a new dimension is about to be added to packet communications in particular, and Amateur digital communications in general.

### RUDAK - WHAT?

RUDAK-U will be able to see half the world at a time, and from almost any location on the planet you'll have access to almost all the rest of it over a 48-hour period. It will have the file store-and-forward ability you're already accustomed to. We're hoping to augment the spacecraft's memory systems with ground-based mass storage facilities.

But let's look at the real-time opportunities. RUDAK may have as many as ten communications channels operational at a time. During these times, multiple QSOs can be carried out using multimedia, digital voice, and so forth. At other times, only a few channels will be operating. Some of these channels will likely be "scheduled" to minimize QRM (oops, I meant "collisions").

*Continued on Page 4*

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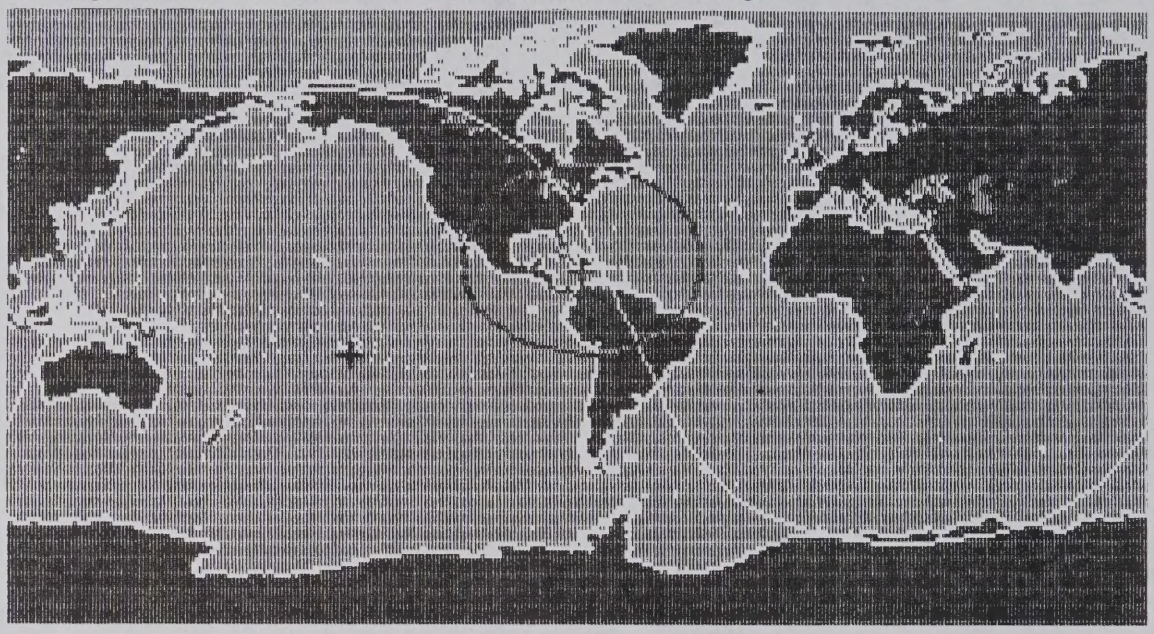
# Satellite Tracking

## with your PC and the Kansas City Tracker & Tuner



The **Kansas City Tracker** is a hardware and software package that connects between your rotor controller and an IBM XT, AT, or clone. It controls your antenna array, letting your PC track any satellite or orbital body. The **Kansas City Tracker** hardware consists of a half-size interface card that plugs into your PC. It can be connected directly to Kenpro 5400A/5600A or Yaesu G5400B/G5600B rotor controllers. It can be connected to other rotor assemblies using our Rotor Interface Option.

The **Kansas City Tuner** Option provides automatic doppler-shift compensation for digital satellite work. The **Tuner** is compatible with most rigs including Yaesu, Kenwood, and ICOM. It controls your radio thru the radio's serial computer port (if present) or through the radio's up/down mic-click interface. The **Kansas City Tuner** Option is perfect for low-orbit digital satellites like the NOAA and Microsat satellites.

The **Kansas City Tracker** and **Tuner** include custom serial interfaces and do not use your computer's valuable COMM ports. The software runs in your PC's "spare time," letting you run other programs at the same time.

The **Kansas City Tracker** and **Tuner** programs are "Terminate-and-Stay-Resident" programs that attach themselves to DOS and disappear. You can run other DOS programs while your antenna tracks its target and your radios are tuned under computer control. This unique feature is especially useful for digital satellite work; a communications program like PROCOMM can be run while the PC aims your antennas and tunes your radios in its spare time. Status pop-up windows allow the user to review and change current and upcoming radio and antenna parameters. The KC Tracker is compatible with DOS 2.00 or higher.

### Satellite and EME Work

The **Kansas City Tracker** and **Kansas City Tuner** are fully compatible with N4HY's QUIKTRAK and with Silicon Solution's GRAFTRAK. These programs can be used to load the **Kansas City Tracker's** tables with more than 50 satellite passes.

### DX, Contests, and Nets

Working DX or contests and need three hands? Use the **Kansas City Tracker** pop-up to work your antenna rotor for you. The **Kansas City Tracker** is compatible with all DX logging programs. A special callsign aiming program is included for working nets.

### Packet BBS

The **Kansas City Tracker** comes complete with special control programs that allow the packet BBS user or control-op to perform automated antenna aiming over an hour, a day, or a week. Your BBS or packet station can be programmed to automatically solicit mail from remote packet sites.

### Vision-Impaired Hams

The **Kansas City Tracker** has a special morse-code sender section that will announce the rotor position and status automatically or on request. The speed and spacing of the code are adjustable.

The **Kansas City Tracker** and **Tuner** packages include the PC interface card, interface connector, software diskette, and instructions. Each Kansas City unit carries a one year warranty. The KC Tuner is not available as an after market upgrade.

- KC Tracker package includes cable for Yaesu/Kenpro 5400/5600 and rotor interface option (to connect to any rotors) ..... $229
- KC Tracker package plus KC Tuner ..... $319
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# Apogee View

## What Do You Think?

*by Bill Tynan W3XO*

This year marks both a landmark in the history of the Amateur space program and a crucial point in determining its future. This 25th anniversary year for our organization, might be considered our "Janus" point - after the Roman god which was depicted with two heads, one looking in one direction and the other in the opposite direction.

Our organization looks back over 25 years of accomplishment. The Radio Amateur Satellite Corporation, which was established in 1969 to carry on the pioneering work of Project OSCAR, not only contributed a great deal to Amateur Radio by building a number of satellites itself, but provided a model and inspiration for the formation of Amateur satellite based organizations in many other countries in all parts of the world. As a result of the formation of these other "AMSAT" organizations, we have informally adopted the "NA" suffix to identify our specific North American based organization. Thanks to the efforts of these other amateur satellite groups, and those of AMSAT-NA, Amateur Radio presently has some sixteen operating satellites freely open to licensed Amateurs anywhere in the world. With the promised imminent launch of UNAM-SAT and RS-15, two more Amateur satellites should soon join that group.

But even more exciting than the look back, the view ahead has the potential of being absolutely mind boggling. Of course, Phase 3D is on everyone's mind. Those who have seen, or will soon see, the actual satellite hardware in the Orlando Integration Facility can appreciate first hand what is to come in less than two years. How we will use it to enhance our enjoyment of Amateur Radio and increase our hobby's already substantial contributions to our various communities and the world as a whole, will be up to us as individual amateurs, and to our national amateur organizations. Of course, AMSAT-NA will assist in this operational aspect where it can; but our principal role, in conjunction with our overseas partners, is in providing the spacecraft.

But should the launch of Phase 3D be the end of the design and construction phase of AMSAT-NA's participation in the Amateur satellite program? In the future, should we limit our efforts to supporting the satellite user community by offering software and publications? Or, should we undertake additional satellite construction projects? If so, what kinds of projects? If we are to continue to be active in satellite design and construction, should we work primarily within our own North American organization, or pool our resources with other overseas AMSAT organizations, as we are doing in the Phase 3D Project? Whether we work alone or with others, where can we continue to find the talented volunteers willing to design and build satellite hardware and create necessary software? Where are the launches to come from? Even piggyback launches are getting more expensive each year. Will the Amateur community supply sufficient financial resources to build and launch future satellites? Should we cultivate cooperative alliances with various university-based satellite construction groups? If we do become involved with such groups, how do we "guide" them to projects which produce spacecraft that are suitable as amateur satellites and have the capabilities we want? What capabilities DO we want? What kinds of satellites should be considered as qualifying as "Amateur Radio" and thus having the use of amateur frequencies? What should our policy be with respect to mixed satellites, those with both amateur and non-amateur payloads? Should we concentrate on low earth orbit (LEO) spacecraft like the MICROSATs, or undertake a major project to build and launch a geostationary bird? But consider, if we go the geostationary route, the financing and technical contributions will have to come from the Western Hemisphere - mostly the U.S. This fact of life was one of the prime considerations which led to the AMSAT-NA Board's decision to shelve the Phase 4 project and concentration our efforts on participation in the International Phase 3D project.

These are some of the weighty questions before the AMSAT-NA Board of Directors. The Board and officers would like to get the opinions of as many members as possible. So, please drop your ideas on the above questions, and any others you can think of, to the AMSAT office in Silver Spring, Maryland.

## RUDAK-U Digital Communications System

*Continued from Page 1*

There is a possibility that there will be a special, bandwidth-efficient 256 kilobit/sec modem aboard the satellite and that RUDAK-U will have the opportunity to connect to it. We're talking serious capability here, like real-time motion video!

Speaking of video, RUDAK-U is expected to be the primary communications path for images from the SCOPE earth-imaging cameras on Phase 3D. It will also be a source of precise information from the on-board Global Positioning Satellite (GPS) experiment.

Some of the time, RUDAK-U will have only one or two downlinks running, but with sufficient power that a ground station with a low-noise front end and a small beam antenna (perhaps 5 or 6 elements, may be fewer) will be able to fully utilize. At other times, when more downlinks are on or high-speed links are in use, a better antenna will be required.

As you can see from this brief sketch, RUDAK will have something for everyone in the digital communications community. RUDAK has something for YOU!

### RUDAK - WHEN?

The design has been worked out at the block level, and detailed circuit design is being completed as this is written.

Engineering prototypes are expected to be built and shaken down in the December 1994 time frame. Flight hardware construction will begin in January and the flight module will be delivered to the satellite integration facility in Orlando, Florida, in March, 1995.

### RUDAK - SOME DETAILS

RUDAK will carry two (2) independent computers. CPU-A will be based on the NEC V53 processor. This processor is a superset of the V40 flying aboard the MICROSATs and scheduled to fly on UNAMSAT. The V53 is flying now as part of AO-27. It will have 16 megabytes of error correcting memory, and sixteen (16) DMA-based communications ports.

CPU-B will be based on the Intel i386EX processor. This is a high-end controller and is being investigated for use on future Amateur spacecraft as well. Like CPU-A, this one will have 16 megabytes of memory, with error correction to help protect against the hazards of radiation upsets. It will have fewer communications channels than CPU-A due to limited DMA resources (8 channels).

For comparison, the MICROSATs have 256 kilobytes of error-correcting memory (1/64th the amount of either CPU on RUDAK-U) and a total of 8-1/4 megabytes of memory (about 1/2 the amount of either CPU on RUDAK). They have six (6) DMA ports.

The CPUs will be tied together by a high-speed first-in first-out (FIFO) buffer. This will effectively enable each CPU to have access to much of the other CPU's memory resources. The modems for RUDAK will interface to the IF switching matrix on P3D. This means a different kind of interface (similar to that pioneered by RUDAK-II aboard RS-14/AO-21) and the ability to operate on multiple frequency bands along with the analog transponders.

One of the design goals of RUDAK-U is to be compatible with existing packet users. Another goal is to be flexible for future operations. Since we expect P3D to be operational for more than ten years, we don't want people to have to use today's (obsolete) technology.

Each CPU will have a modem module. Each modem module will have the following lineup:

(1) One 1200 bps Manchester uplink/PSK downlink for low speed, lower-power operation.

(2) Two 9600 bps FSK uplink/downlink for "typical" operation. These modems will be switchable to 19.2 kbps and perhaps as fast as 38.4 kbps.

(3) At least two DSP-based modems. These will allow operation at reasonable data rates (we are looking at making them capable of 56 kbps operation) as well as more complex modulation schemes. They will of course be able to provide compatibility with today's satellite standards.

### RUDAK - HOW

RUDAK-U is happening because some volunteers are pouring countless hours of toil and love into it. These volunteers have reduced the dollars required to about $60,000. TAPR[1] has set up a special fund for supporting this project. Please consider making a donation[2]. Consider it an investment in the future of Amateur digital communications.

Just so you don't think your money might be spent on a Caribbean Cruise, here is a condensed breakdown of the budget:

| Module | Flight Unit | Engineering Unit |
|---|---|---|
| CPU-A | $ 59 | $ 330 |
| CPU-B | 620 | 310 |
| Memory x 2 | 508 | 1,340 |
| Modem x 2 | 1,760 | 1,140 |
| Total | $14,890 | $5,600 |

NOTE: A complete system includes one CPU-A, one CPU-B, two MEMORY and two MODEMS.

There will be four (4) engineering units and two (2) flight units. So the total cost will be as follows:

| | |
|---|---|
| Parts | $52,180 |
| Printed Circuit Board Costs | 8,800 |
| Travel, Meetings, Initial Integration | 5,500 |
| Parts Discounts | (2,880) |
| Estimated Total | $63,600 |

Like the rest of P3D, RUDAK-U is a truly international effort. The main players in the technical team include Lyle Johnson (Project Manager), Peter Guelzow, Chuck Green, Harold Price and Jeff Ward. We are all licensed Amateurs with long experience in volunteer service to Amateur radio, Amateur packet radio and Amateur Satellites. As you can tell, we're very excited about this project.

Won't you help us make this dream a reality?

1) TAPR, 8987-309 E. Tanque Verde Road #337, Tucson, AZ 85749-9399.

2) If you are a U.S. taxpayer itemizing deductions, such donations may be tax-deductible. Consult your tax advisor. Your mileage may vary.

# *Notes from the Field . . .*
# Phase 3D Progress Report

*by: AMSAT Integration Facility Staff*

Work is proceeding on schedule at the AMSAT Integration facility in Orlando. After receiving the spaceframe from Weber State University and disassembling it, the spaceframe panels were prepared for painting. Special spacecraft-qualified epoxies are used which won't outgas in a vacuum. A local auto painting shop was found that was willing to do the painting. When assembled there must be good electrical conduction between all of the spaceframe panels, so each of the spaceframe panels was masked to protect areas which were not to be painted. Stan Wood, WA4NFY, Chuck Hennessey, W4AT, and Frank Lavra built a set of support frames out of two-by-fours to hold the pieces as they were painted and Frank built a set of custom-made storage boxes for the components.

After the painted panels were returned to the facility they were reassembled into a spaceframe using the flight rivets. Anyone who has worked on an aircraft will appreciate the amount of riveting that had to be done.

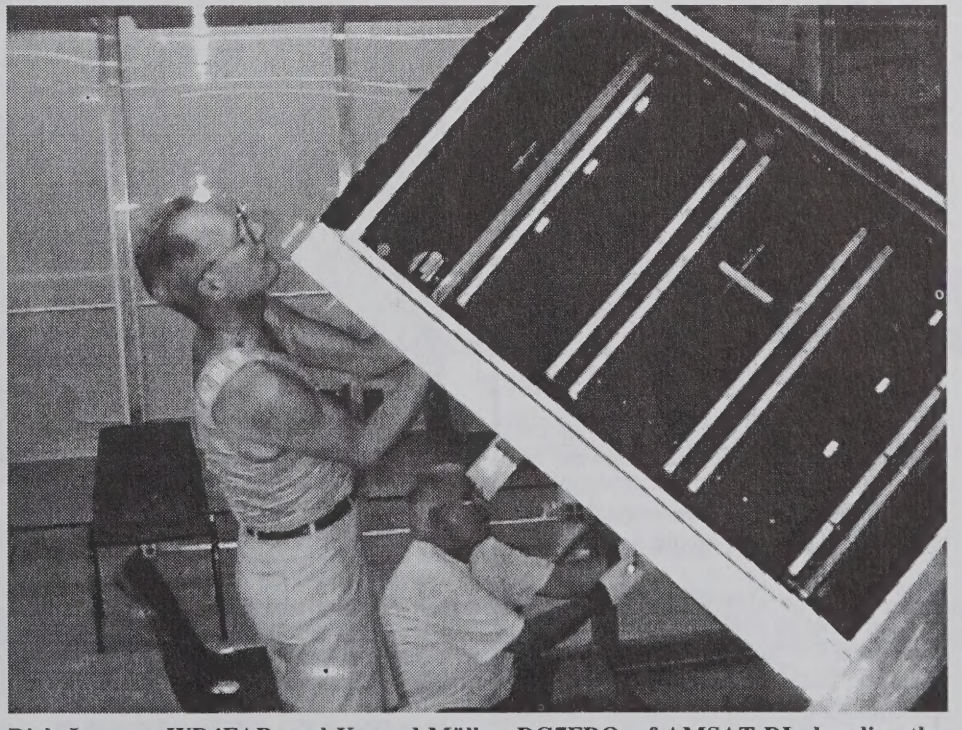
Up to this point the spaceframe was sitting on two tables in the cleanroom. It was realized that we would need better access to the spacecraft during the assembly. Stan designed a handling fixture which was fabricated at a local welding shop. The base of the fixture has four casters and can easily be rolled around by one person, despite its weight. Three bolts hold the spacecraft on a rotating frame, using the same bolt holes which will hold the spacecraft to the launch vehicle a couple of years from now. The spacecraft is held like a rotisserie, permitting it to be rotated for easy access to all of the components. The rotating frame has a disk brake and can easily be set at any convenient position.

The most difficult task of the assembly came next - bonding the heat pipes to the frame. Due to the size of Phase 3D an active thermal management system is a necessity. As one side is heated by the sun it will be much hotter than the other. In addition the electronic boxes will generate heat which must be radiated to space. The heat pipes are four long tubes with square cross sections bent into a hexagonal shape to mount on the inside of the equipment panels. The inside of the heat pipes includes fine grooves and each pipe contains a charge of anhydrous ammonia. Great care had to be taken to avoid damage to the heat pipes while working on the spacecraft. In space, heat pipes work like a heat conductor, transferring heat from one side of the spacecraft to the other. On the 'hot' side of the spacecraft the heat will vaporize the ammonia. On the 'cold' side the ammonia condenses into a liquid - releasing its heat. The grooves act like a wick to transfer the ammonia back to the hot side of the spacecraft. The advantage of a heat pipe system is that it doesn't have any moving parts and is a sealed system, ensuring high reliability over Phase 3D's lifetime. AMSAT Vice President of Engineering Dick Jansson, WD4FAB, is a thermal engineer by trade and did an excellent job developing the heat pipe system. Dick and Konrad Müeller, DG7FDQ, of AMSAT-DL, bonded the heat pipes to the equipment panels over two weeks and we all breathed easier when the job was completed.

Konrad deserves special praise for his tireless work. He came to Orlando for two weeks to work on the spacecraft. In those two weeks he was always the first person at the facility each morning ready to work, and he never took a day off during his stay. Konrad had mentioned that the only space launches he had seen were the other Phase 3 spacecraft - and all of them from inside the blockhouse in French Guiana, so we arranged for a space shuttle launch in his honor. Konrad and Frank Larva went to the Kennedy Space Center to see the STS-68 launch of Endeavor - but only got to see the engines shutdown on the pad due to an over temperature reading on an oxygen turbopump. Sorry Konrad - we'll try better next time.

During Konrad's stay we had another international visitor, Miki Nakayama, JR1SWB, of Japan. Miki's JAMSAT group is building the CCD cameras and was fascinated with the spacecraft construction.

One of the nicest features of the Spacecraft Integration Facility is a large backyard - large enough for a tractor-trailer when it comes time to ship the assembled spacecraft. For now the backyard includes a 20 meter antenna (listen for us on the AMSAT nets) and a full OSCAR setup with 70 cm and 2 meter Yagis with Az-El motor drives. It also includes our antenna test range. Stan Wood designed a motorized fixture to put



**Dick Jansson, WD4FAB, and Konrad Müller, DG7FDQ, of AMSAT-DL, bonding the Heat Pipes to the Equipment Panels.**

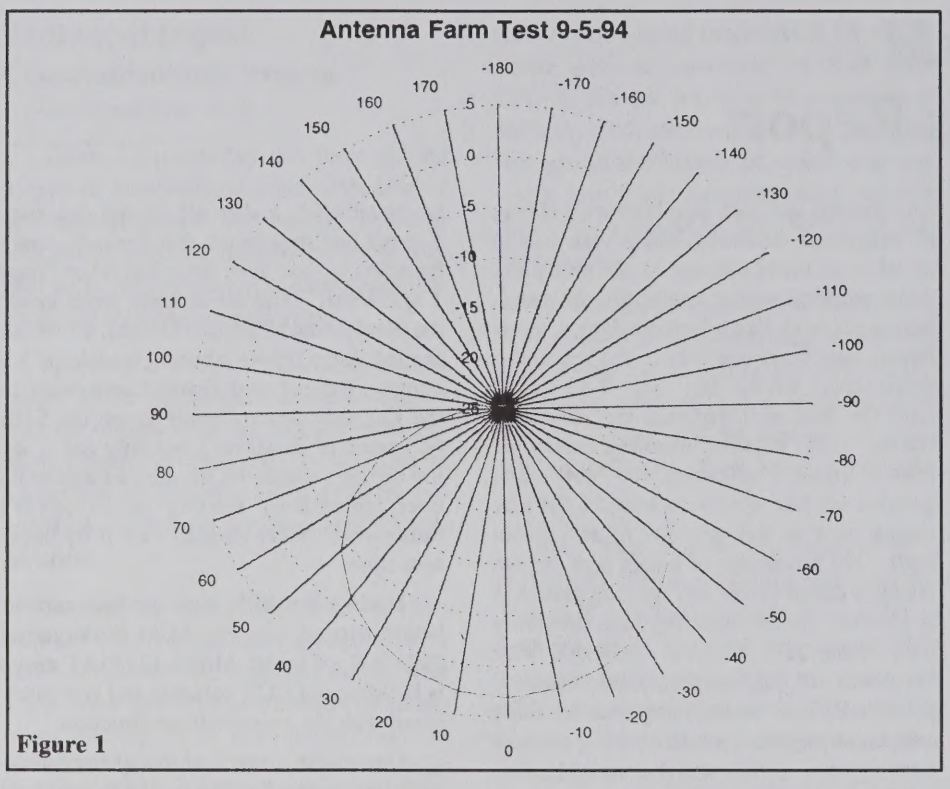



**Figure 1**

test antennas 8 meters (25 ft.) above the ground. The OSCAR antenna is aimed directly at the test antenna with a 1 watt carrier. The test antenna is rotated through 360 degrees and the power received is recorded. Figure 1 shows one of our earliest tests with a reference antenna - an excellent pattern.

By the time of the Symposium there should be a full-size mockup of the top of the spacecraft with places for all of the different antennas that are planned to be mounted. This will be used to test each antenna individually and together to measure overall performance and cross-band interference effects.

The first Phase 3D flight components to arrive in Orlando were the Russian-built propellant tanks. Six flight tanks, plus a spare which was purposely over pressurized to destruction, were shipped from Russia to AMSAT-DL, and then to the facility. They sat in storage for several months, waiting for the other components to arrive. When the spaceframe was assembled we finally got to take the tanks out of their shipping containers for a fit check.

Danny Orban, ON4AOD, of Belgium, visited the facility during his vacation. He's building the 24 GHz transmitter and was quite happy to see the spacecraft up close. Danny, Dick, and Stan worked out the mounting of the 24 GHz module and the horn antenna during his Florida stay. Danny's luck was better than Konrad's, he did get to see a space shuttle launch - STS-64.

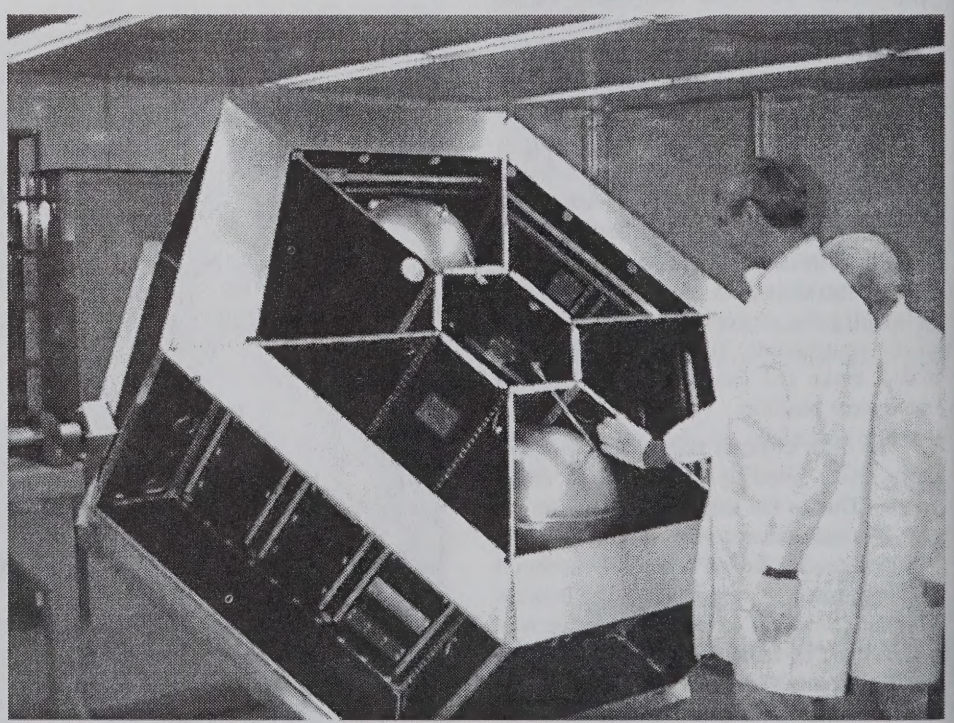
As the work is progressing on the spacecraft, preparations are being made for the Annual Meeting and Space Symposium. With over 400 visitors expected there's plenty of work to get the facility ready - in addition to our normal work on the spacecraft.

**INSTANTTRACK UTILITIES**

A disk of utility programs. It users will find some very useful. Pacsat users will appreciate the two KISS related files. The single disk contains the following:

ITPASS - Outputs a table of upcoming passes with AOS, LOS and maximum EL.
ITSORT - Rearranges IT's satellite database using your own text editor.
ITSTAMP - Adds AZ / EL / RANGE to a timestamped ASCII log file.
DISPANG - Displays OrbitDRV antenna angles in upper right corner of screen.
DUMMYKCT.ZIP - Assembly language source for the dummy RotorDRV.
DRVSVC.DOC - Specification for the Kansas City Tracker software interface.
KCTHW.TXT - Reverse-engineered hardware data on the Kansas City Tracker
KISS2ASC - Converts a KISS binary log file to readable ASCII.
KISSFILT - Selectively filters a KISS log file by callsigns, etc.

Members & non-members $15.



**Stan Wood, WA4NFY, and Chuck Hennessey, W4AT, examine the Phase 3D spaceframe with two propellant tanks installed for a fit-check.**

# Dish Feeds For Mode S Reception

*Ed Krome KA9LNV*
*1023 Goldfinch Dr.*
*Columbus Indiana 47203*

### Introduction

For several years, I used a single loop Yagi for AO-13 mode S reception. This was adequate, but sometimes just barely. In the interest of finding more gain (and the eternal quest for "armchair" reception), I started experimenting with small dish antennas. This paper offers the result of that investigative legwork and quite a bit of actual testing of parabolic antennas and feeds. An extensive bibliography is provided for those who desire additional information. This paper is purely practical and not intended to tell everything there is to know about this type of antenna. Its goal is to provide background for understanding and to offer hardware advice specifically for the reception of mode S.

### Dish Basics

A parabolic reflector, or "dish", is a reflector that focuses parallel incoming rays on a single point, called the focal point. The relationship between the location of the focal point and the geometry of the dish surface is defined (and dishes are characterized by) by the ratio of the focal length to the diameter, usually called the f/d. F/d's from .25 (where the focus of the dish is very close to the dish for a given dish diameter; this is called a "focal plane" dish because the focus is equal to the depth of the dish) to 1 (where the focus is a distance from the dish equal to the outside diameter of the dish) are practical. Is there one best? Well, like most things in life, each has its strong and weak points. We make trade-offs to fit our requirements (or we make do with what we can get our hands on!).

### Feed Basics

Now we will leave reflectors for a minute and move to the other part of a parabolic antenna, the feed. Since the function of the dish itself is to focus all the energy coming into it on a specific point, the purpose of the feed is to efficiently gather all that energy. In Yagi antennas, the longer the boom, the higher the gain. This gain is obtained at the expense of beam width. In other words, the longer the antenna, the more closely you have to point it at the intended target. This beamwidth characteristic, rather than the gain number, is what we are interested in for feeds for parabolic antennas.

Beamwidth is characterized in total degrees either side of center, where the gain of the antenna drops off some specified amount. In normal Yagi characterization, beamwidth is defined to half-power points, where the gain drops off 3 dB from the maximum. However, for dish antennas we need beamwidths at 10 dB points. Standard practice for maximum efficiency is to get a feed whose beamwidth is such that the strength of the main lobe is 10 dB down at

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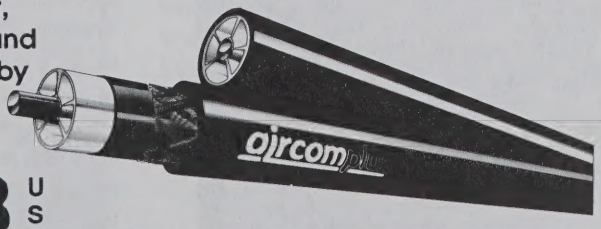


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the edges of the dish. This pattern of the feed on the dish is referred to as "illumination". There is also a phenomenon called "space loss" which is determined by the distance from the feed to the dish at various angles and increases with decreasing f/d of the dish. See VE4MA's articles for additional information.(1)

### Antenna Patterns and Sidelobes

An ideal antenna would have a single gain lobe pointing directly off the end. All the energy would be concentrated in a single, defined beam. In the real world, things are not quite that nice. Besides the central main lobe, antennas have all kinds of other minor lobes shooting off in all kinds of strange directions, including backwards. A common term, the front to back ratio, is the difference in gain an antenna has straight out the front compared to the gain it has straight out the back. Yagi antennas also have sidelobes, which are usually strongest near the main lobe. On either side of the main lobe, there will be a sharp drop off in gain, called the first null. Then the gain will increase up to some maximum (hopefully less than the strength of the main lobe), then drop off again to a null, then so on to other lobes. The gain of a Yagi can be estimated from the angular location of the first nulls and the strength of the first sidelobes (2). Now, you may ask, why all this business about sidelobes? If the side lobes are strong, they will pick up either other signals or just plain noise which will interfere with the desired signal. When we are dealing with UHF, this noise pickup is very important. Remember that the sky has a noise temperature of only 3-15 degrees K, and a good preamp isn't much more; maybe 80-100 degrees K total. But the earth is 300 degrees K. If your sky-pointing antenna is getting a good bit of the ol' Earth in it's strong sidelobes, the noise in the whole system goes up in a hurry. So, for space receiving antennas, we want to minimize Earth noise pickup. Obviously, for a dish antenna feed, we want one that only gets the signals reflected from the dish itself, not the nice warm ground around the dish. In practice, it is common to "under-illuminate" a dish for receiving, where the gain is allowed to drop off more than 10 dB at the dish edges, because this minimizes noise pickup and improves the performance of the dish.

### Dish Surface Accuracy

Another point, near and dear to the hearts of homebrewers like me, is surface accuracy. Just how close to parabolic does the surface of a dish have to be to work? Fortunately, there is not a black and white answer here. Dish inaccuracies are not the difference between "it does work" and "it doesn't". The less accurate the dish surface, the more reflected energy misses the focus and the lower the gain. Generally, if the dish surface accuracy is within .1 wavelength at the frequency of interest, the effect on gain will be minimal (3). At 2400 MHz, that amounts to about 1/2 inch. Also, this rule applies to the reflective nature of the dish. While a solid dish seems like the best way to go, a solid dish has a lot of surface area to catch wind, snow, etc. and put a lot of strain on its mountings and rotors. A better approach is to use a dish with a wire mesh reflector, that will have much less wind loading, is lighter and generally easier to handle. If the size of the mesh is less than .1 wavelength, it will appear solid electrically. A larger mesh will result in reduced efficiency


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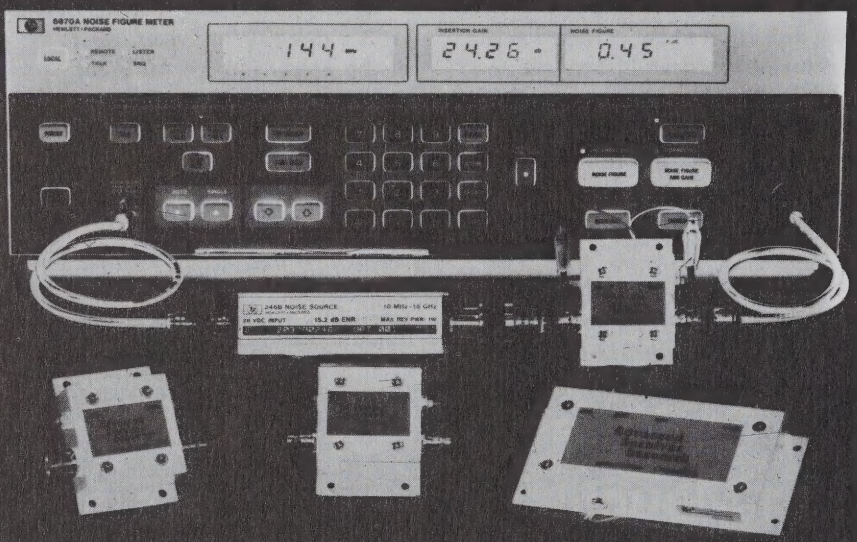

| Receive Only | Freq. Range (MHz) | N.F. (dB) | Gain (dB) | 1 dB Comp. (dBm) | Device Type | Price |
|---|---|---|---|---|---|---|
| P28VD | 28-30 | <1.1 | 15 | 0 | DGFET | $29.95 |
| P50VD | 50-54 | <1.3 | 15 | 0 | DGFET | $29.95 |
| P50VDG | 50-54 | <0.5 | 24 | +12 | GaAsFET | $79.95 |
| P144VD | 144-148 | <1.5 | 15 | 0 | DGFET | $29.95 |
| P144VDA | 144-148 | <1.0 | 15 | 0 | DGFET | $37.95 |
| P144VDG | 144-148 | <0.5 | 24 | +12 | GaAsFET | $79.95 |
| P220VD | 220-225 | <1.8 | 15 | 0 | DGFET | $29.95 |
| P220VDA | 220-225 | <1.2 | 15 | 0 | DGFET | $37.95 |
| P220VDG | 220-225 | <0.5 | 20 | +12 | GaAsFET | $79.95 |
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| P432VDA | 420-450 | <1.1 | 17 | −20 | Bipolar | $49.95 |
| P432VDG | 420-450 | <0.5 | 16 | +12 | GaAsFET | $79.95 |
| Inline (rf switched) | | | | | | |
| SP28VD | 28-30 | <1.2 | 15 | 0 | DGFET | $59.95 |
| SP50VD | 50-54 | <1.4 | 15 | 0 | DGFET | $59.95 |
| SP50VDG | 50-54 | <0.55 | 24 | +12 | GaAsFET | $109.95 |
| SP144VD | 144-148 | <1.6 | 15 | 0 | DGFET | $59.95 |
| SP144VDA | 144-148 | <1.1 | 15 | 0 | DGFET | $67.95 |
| SP144VDG | 144-148 | <0.55 | 24 | +12 | GaAsFET | $109.95 |
| SP220VD | 220-225 | <1.9 | 15 | 0 | DGFET | $59.95 |
| SP220VDA | 220-225 | <1.3 | 15 | 0 | DGFET | $67.95 |
| SP220VDG | 220-225 | <0.55 | 20 | +12 | GaAsFET | $109.95 |
| SP432VD | 420-450 | <1.9 | 15 | −20 | Bipolar | $62.95 |
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and more noise from the warm Earth behind the dish.

### Feed Characteristics

A question I have been asked on the air is "if I make my dish feed have more gain will it help my reception?". The answer here is a definite maybe. Remember when we talked about the fact at dishes come in various f/d's? And we want to absorb all the energy the reflector puts at the focus? And that antennas have beamwidths and patterns? The whole idea of a dish feed is to "efficiently illuminate the dish". That is, the beamwidth pattern of the feed must be matched to where it is mounted (at the focus) relative to the dish. As an example, let us take a pair of dishes, each the same diameter, say 30 inches. One is a "deep" dish with an f/d of .3. This means that the focus of the dish is .3 times the diameter of the dish, or 9 inches away from the dish. The other dish is a real flat fellow, with an f/d of .7. This dish has a focus 21 inches away from the dish. The feed's beamwidth should be such that the gain of the main lobe drops off 10 dB at the outside edge of the dish.


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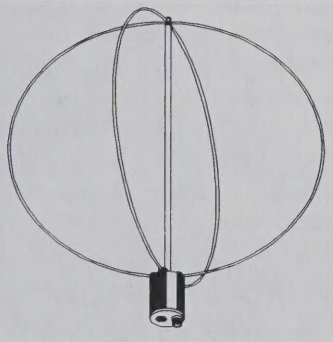

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So, going back to our sample dishes, the beamwidth of the feed used to illuminate the deep, .3 f/d dish must have a -10 dB beamwidth equal to the subtended angle of the edges of the dish at the focus, or 160 degrees. But the .7 f/d dish, with it's focus much further away from the dish, requires a -10dB beamwidth of only 75 degrees. Clearly, one feed cannot do both!

### What Type Dish Is Best?

So, should we use a deep or a shallow dish? After questioning a number of people who really understand this stuff, and getting several somewhat conflicting theories, there appears to be little functional difference between deep and shallow dishes, assuming correct illumination. Physically, a shallow (large f/d) dish is more cumbersome, with its feed sticking way out in front of the dish, and would require more counterweighting than would a deep dish with its focus very close to the dish. The deep dish makes a nice, compact package. But, a shallow dish deals with the section of the parabolic curve close to the center, where changes in curvature occur slowly and is therefore easier to construct. Also, the location of the feed is not as critical on a long focal length (shallow) dish. Shallow dishes become mechanically cumbersome and the feeds get quite large in order to restrict the beamwidth. A large feed may shadow a significant area of the dish itself. A deep dish, on the other hand, is more critical from a construction point of view in that it is more difficult to accurately reproduce the rapid changes of the parabolic curve further from the center of the dish. Also, it is difficult to make an efficient illuminator for a very deep dish.

Commercial dish antennas run the gamut from very deep to quite shallow, although .35 to .5 appear to be the most common. Because of the difficulty in obtaining proper illumination characteristics, .25 and .3 f/d dishes are not common in amateur circles. So the most useful range of dish dimensions tend to be in the .4 to .6 f/d range, where a number of good, efficient feeds have been published. If you are building a dish, that is a good range to think about. If you get a commercial dish, hope that it has a usable f/d! (1,4)

### Polarization

Mode S is circularly polarized, and while linear polarization is usable (loop Yagis are linear), circular adds a few dB more gain. Circularity may be obtained either directly from the design on the antenna (helix) or indirectly from feeding 2 radiating elements mounted at right angles to each other in quadrature (90 degrees out of phase) (1).

Circular polarization is used at and above 1296 MHz for moonbounce. When using circular polarization for moonbounce, it is necessary to receive on one polarity and transmit on the other (reflection off the Moon changes the polarization sense). This requires the ability to switch quickly. Fortunately, for Mode S, a single polarity is satisfactory.

The hand of circularity is critical. True circular polarization causes over 30 dB of attenuation between right hand and left hand. For receiving AO-13 directly, the helix must be wound right-handed. But for a dish feed, it must be wound left-handed since reflection off the dish surface changes the hand of polarity.

### Types of Feeds

The simplest dish feed is probably the WA3RMX tri-band feed published in QST (5). This simple printed circuit board feed should work fine with a 3' or larger dish, in the .3 to .4 f/d range. I have run swept return loss plots on this feed and while it is designed for 2304 MHz, it appears satisfactory at 2401 also. It is linearly polarized.

Another simple feed is the coffee can, more elegantly referred to as the "feed horn" (6,7). This is simply a standard 1 pound coffee can with a single probe mounted in it. Coffee can feedhorns are nice in that they are reproducible, have about 10 dB of gain over an isotopic radiator and do a good job of illuminating a .5-.6 f/d dish. I have used them and they work adequately. For best efficiency, the return loss should be adjusted, but they will work adequately if built to spec. This single-probe type feed is linearly polarized.

The helix is the most basic feed with intrinsic circular polarization, though they are not always truly circular. We will talk about the helix in detail.

The moonbounce guys are the ones who have developed dish feeds the most, since they demand the most from their antennas. Frequently used feeds include dipoles mounted over reflectors, EIA standard gain antennas and a wild assemblage of crossed

dipoles and multi-fed horns feed in phase to produce desired polarization characteristics. See the included references for more details (1,2,3,8), as these are beyond the scope of this paper.

**The Helix**

First, helices come in a variety of types. The general geometry determines how the helix will radiate. When the helix diameter is small ( < 1 wavelength circumference) and the spacing between turns very close, the helix will radiate at right angles to the axis, called "normal" mode. HT's have normal mode helixes in their rubber ducky antennas. An "axial mode" helix, with circumference of about 1 wavelength and a spacing around 1/4 wavelength, radiates out the end, parallel to the axis. Much work on helixes has been empirical, so most design data exists for about a 13 degree helix pitch angle. Beamwidth and gain are related to number of turns (2).

The little helix, however, is not quite as benign a beast as it appears. I had never had particularly good results with them and wondered why. Some serious investigation and experimenting has shed some light on the subject.

First, while we have all heard how broadband they are, this may be true of gain, but it is not true of return loss, which appears to be quite narrow. And return loss is the measure of how efficiently energy is transferred (better RL means less reflection) between two devices. Also, just because a helix is round doesn't mean it is circularly polarized (return loss also greatly influences circularity).

A problem with helix feeds is feedpoint impedance. Most literature indicates that the typical helix has about a 140 ohm impedance. While it could be used with a preamp with a matching 140 ohm impedance, most common equipment has a 50 ohm impedance and the two must be matched to get efficient energy transfer between them. Although separate 1/4 wave stubs and matching sections could be used to convert the 140 ohms to 50 ohms, a popular method is to incorporate the matching transformer directly on the helix itself. This matching transformer is in the form of a widened first quarter turn of the helix itself. That fin you see on well designed helices is not a capacitor, but actually an impedance transformer. It accomplishes its transformation by its proximity to the ground plane reflector. This is made very close to the reflector (low impedance) at the connector, tapering out away from the reflector for the first quarter turn (and quarter wavelength). Works fine, but herein lies the problem afflicting most homebrew helices: if a proven design isn't duplicated exactly, it might work, but not very well! "Close" can yield some surprisingly different characteristics. By experiment, I have found that while you set return loss with the geometry of the matching section relative to the reflector, you set the frequency of the return loss null by trimming the end of the helix. The two are somewhat interactive. Frequency of best null is repetitive; if you continue to prune the end of a helix a little bit at a time, the frequency of the return loss null will continue to move up and deteriorate, then disappear and start over again at a lower frequency. Similar peaks occur at half turn intervals, with best peaks occurring when the overall number of turns are odd quarters; e.g. 4 1/4 turns, 4 3/4 turns. This proved true on a variety of short (<9 turn) helices.

The ideal way to set up a helix feed is to build it to some computed geometry, then tweak it by bending and trimming while observing swept return loss. An alternative is to tweak the antenna for best return loss at a single frequency. But the way most of us will have to do it is to duplicate a published design.

By trial, a 5 turn helix has a half-power (-3 dB) beamwidth of around 50 degrees and -10 dB points of a little over twice that. This would indicate that a 5 turn helix would be suitable for proper illumination of a dish with a subtended angle of maybe 110 degrees, which is pretty close to an f/d of .5, a nice common value. Flatter dish, more turns. Shallower dish, fewer turns.

The following 4 3/4 turn design is one that has proven satisfactory for use with a .5 f/d dish (or really anything close) and provides quite good on-the-air performance. As I said, to expect this feed to work properly, you must duplicate it exactly. The construction of this feed is similar to that published by G3RUH, and since James did such a complete job of detailing his construction techniques, I won't repeat them here. Follow his instructions as noted, with the following exceptions:

1) Use #8 (.125") bare copper wire.

2) Mark the wire every 5.75"; this is the length of one complete turn and insures that the helix turns will be equal after winding and stretching.

3) The total 4 3/4 turn helix will require 27 5/16" of wire, plus a 3/32" nib to be filed to fit into the solder pocket of the N connector.

4) Turns spacing must be 1 1/4". Make a spacing mandrel by marking a 1 1/2" dia. rod every 1 1/4 inches (this will help get the spacing between turns right).

5) In order to position the impedance matching section properly, tape a .040" drill bit to the reflector as close as possible to the solder pocket of the N. Then tape a 5/32" (.156") drill 1/4 turn away at right angles to the first drill. These are your spacing gauges. Set the matching section on the 2 drill bits and into the solder pocket on the N and solder away. If it falls apart or doesn't wind up nice and even, start over.

6) This design is set up to take weatherproofing into account and won't work right without it. Clean all flux off the start of the helix. Put a glob of RTV (I used Dow Corning 100% Silicone Sealant - Clear) on the start end of the helix and around the end of the connector to keep water out. Then put another (3/8" dia) glob at the end of the matching section, between the end of the fin and the reflector. This adds mechanical rigidity to the helix, which it really needs. Note that the RTV has a dielectric constant quite different from air; if you set the return loss of the helix in air, then add RTV, it will change drastically. So these dimensions were finalized when the RTV was in place.

7) I used a 3/4" wood dowel rod (varnished) through the center of the helix as a support. It has little effect on return loss. See OTHER THOUGHTS for other notes on supports.

8) Follow the instructions on using the Sun as a noise source in order to set the location of the helix in the dish. The helix must be mounted with its "phase center" at the focal point. Where is the phase center? On this helix, it appears to be about 1 1/2 inches in front of the reflector. So my 16 1/2" focal length dish got the feed's reflector positioned about 18 inches from the dish. While there may be a scientific method of finding the phase center, the Sun works quite

well. It makes a really significant difference in dish performance.

### Other Thoughts

This is the random but useful thought department.

- A useful addition to your dish is a small reflective cone directly at the center of the dish. The idea here is to reflect any energy radiated by the feed away from the feed and not directly back into it. The center of the dish is shadowed by the feed anyway and doesn't add to the signal capture. This also seems to reduce the variation in measured return loss as the position of the feed is adjusted.

- The popular small TV link dishes marketed by W1XT and Conifer are also parabolic antennas, but they have a linearly polarized feed dipole with reflector. No adjustment is necessary (or possible).

- Patch antennas (10) make satisfactory feeds for very deep dishes. Certain designs are inherently circularly polarized. Problem is that they are very touchy and do not appear to be home-buildable without network analysis gear.

- W3IWI had a very interesting concept in a helix antenna at the Central States VHF Society meeting that he called the "heli-bowl". It consisted of a 2 turn helix on a perf-board form, with a coaxial matching section, mounted in a flat-bottomed stainless bowl. It performed quite well on the antenna range.

- Don't wind a helix on a lossy form. PVC pipe is lousy and fiberglass isn't much better. Air-supported appears best for very small helices. However, it does appear that adding a small diameter metal tube through the center of the self-supported helix for mounting has little effect on the return loss. But this is only true if the metal tube is exactly centered in the helix; the effects of lack of concentricity are graphic on a swept return loss setup and rapidly ruin the return loss as well as fouling up the pattern.

- Low-temperature silver hobby solder stands up best to outdoor service. Clean the flux off after soldering.

- Return loss testing was done with an HP 8690A sweep generator and SMA directional couplers feeding an HP 1416A indicator, and spot checked with a slotted line.

And So . . .

This is certainly not the last word on the subject, but hopefully provides some insight on small parabolic reflector antennas and feeds. Please consult the references listed for additional information.

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### Other useful references:


- G. R. Jessop G6JP VHF/UHF Manual (RSGB)

- Harold Reasoner K5SXK "Microwave Feeds for Parabolic Dishes" Proceedings of Microwave Update 1989 (ARRL)

- J.E. Pearson KF4JU, "Modified Feed Antennas for Parabolic Dishes" Proceedings of Microwave Update 1991 (ARRL)

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# Memory Lane?

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*Coton, Cambridge*
*CB3 7PS, England*
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***This article initially appeared in the OSCAR NEWS (AMSAT-UK). The editor is indebted to Ron Broadbent, G3AAJ, for providing the accompanying figures.***

**Introduction**

Data bits in Oscar-13's memory get corrupted from time to time. If this were to happen in your home computer, it would almost certainly "crash." Yet AO-13's computer carries on unaffected. How do we know that memory bits get flipped? What is the physical construction of the memory? How does the machine take corrective action? How has it performed over six hard years? And why the ambiguous title?

Oscar-13 has a 32 kbyte memory provided by 6 Harris HM6564 SRAM hybrids. Each HM6564 package contains 16 Harris 6504 4k x 1 dies, arranged as 16k x 4 bits. So the total memory is 32k x 12 bits. These 12 bits comprise the normal 8 bit byte, plus

## Current Amateur Satellite Frequencies

| Satellite | Callisgn | Uplink | Downlink | Type |
|---|---|---|---|---|
| AO-10 | | 435.03-435.18 LSB/CW | 145.975-145.825 USB/CW | Mode B Analog |
| AO-13 | | 435.423-435.573 LSB/CW | 145.975-145.825 USB/CW | Mode B Analog |
| AO-13 | | 435.603-435.639 USB/CW | 2400.711-2400.749 USB/CW | Mode S Analog |
| FO-20 | | 145.9-146.0 LSB/CW | 435.9-435.8 | Mode J Analog |
| AO-27 | | 145.85 FM | 436.80 FM | Part-Time Repeater |
| AO-21 | | 435.016 FM | 145.987 FM | Part-Time Repeater |
| RS-10 | | 145.865-145.905 USB/CW | 29.360 - 29.400 | Mode A Analog |
| RS-12 | | 21.21-21.25 USB/CW | 29.41-29.4 | Mode K Analog |
| AO-16 | PACSAT | 145.90, .92, .94, .96 FM | 437.0513 SSB | 1200 Baud PSK |
| DO-17 | | | 145.825 FM | 1200 Baud AFSK/ voice |
| WO-18 | | | 437.104 SSB | 1200 Baud PSK (img) |
| LO-19 | LUSAT | 145.84,.86,.88,.90 FM | 437.1258 SSB | 1200 Baud PSK |
| FO-20 | 8J1JBS | 145.85,.87,.89,.91 FM | 435.91 SSB | 1200 Baud PSK |
| UO-22 | UOSAT5 | 145.9, .975 FM | 435.12 FM | 9600 Baud FSK |
| KO-23 | HL01 | 145.85, .90 FM | 435.175 FM | 9600 Baud FSK |
| KO-25 | HL02 | 145.98 FM | 436.5 FM | 9600 Baud FSK |
| IO-26 | ITMSAT | 145.875, .90, .925., 95 FM | 435.822 SSB | 1200 Baud PSK |
| POSAT | POSAT1 | 145.975 FM | 435.2777 FM | 9600 Baud FSK |

1) Frequencies shown are without Doppler compensation. For typical digital satellite pass the original signal will be about 8 kHz higher than what is shown.
2) WO-18 Webersat transmits experimental and image data and can be captured in KISS mode via PB or TLMDC.
3) Except for FO-20 the digital sats use a program suite containing PB/PG/PFHADD/PHS or WISP. The broadcast callsign (in PB.CFG) is the satellite's callsign with an SSID of -11. The connected mode callsign (in PG.CFG) is the satellite's callsign with an SSID of -12.
4) When in mode JD, FO-20 can be worked with any packet program. Connect to 8J1JBS. FO-20 currently alternates between modes JA and JD on a weekly basis. Check ANS bulletins for schedule.
5) AO-10 is no longer controllable but the transponder works when the satellite is in sunlight.
6) For AO-10 and AO-13, transmit LSB, receive USB. As transmitted frequency is increased the received frequency will decrease (inverting transponder).
7) AO-21 currently operates on a 10 minute schedule with FM repeater, WEFAX image transmission, and 1200 baud AFSK telemetry in each cycle.

4 vital parity bits that are used for EDAC (error detection and correction).

With this arrangement, each 12 bit byte is spread across 12 memory dies spatially separated by large (in semiconductor terms) distances. This ensures that it is extremely unlikely a radiation "hit" will corrupt more than one bit in the same byte. The memory chips are radiation hardened, cost a small fortune, and were donated to AMSAT by Harris Semiconductors. Further radiation resistance is achieved by surrounding the 6564 chips by a box with thick metal walls and lids of sheet tungsten.

To WRITE a byte to memory, it is first passed to the EDAC circuit which generates the 4 extra parity bits, and then all 12 bits are written. On READ, 12 bits are read out, passed again through the EDAC logic which corrects single bit errors. The validated 8 bit byte is then sent to the computer. If an error is detected a hardware counter is also incremented. Periodically (once per MA count) this counter is checked for a change, and, if so, a flash block of telemetry is stored in the "event buffer". This holds sixteen such events, and they are sent down in rotation in the 512-byte PSK "Q" blocks in byte positions 256-383, just before the live telemetry, bytes 384-511.

A read operation doesn't, however, replace the corrected byte in memory. Instead this function is performed explicitly by software later. Every 20 ms, 16 bytes are read out of memory and written back again with correction if necessary. This "wash" operation cleans up 32k of memory every 40 seconds.

### EDAC Memory Circuits

Circuits to perform error detection and correction are delightfully simple. In the

# Satellite Orbital Elements

*by Ray Hoad, WA5QGD*

| Satellite | AO-10 | UO-11 | RS-10/11 | AO-13 | FO-20 | AO-21 | RS-12/13 |
|---|---|---|---|---|---|---|---|
| Catalog Number | 14129 | 14781 | 18129 | 19216 | 20480 | 21087 | 21089 |
| Epoch Time | 94195.81899517 | 94199.48919451 | 94197.30647920 | 94196.85984906 | 94196.43656308 | 94197.22316383 | 94198.89454776 |
| Element Set | 290 | 708 | 926 | 931 | 705 | 489 | 708 |
| Inclination | 27.0497 | 97.7853 | 82.9266 | 57.7662 | 99.0371 | 82.9454 | 82.9212 |
| RA of Node | 317.9184 | 212.7468 | 307.3174 | 241.7882 | 342.9206 | 121.2318 | 348.6696 |
| Eccentricity | 0.6025942 | 0.0011606 | 0.0010629 | 0.7219935 | 0.0539924 | 0.0036264 | 0.0030577 |
| Arg of Perigee | 194.3808 | 164.4932 | 309.9250 | 345.8198 | 275.4857 | 5.6499 | 25.1580 |
| Mean Anomaly | 135.3303 | 195.6634 | 50.0970 | 1.7627 | 78.4920 | 354.5058 | 335.1056 |
| Mean Motion | 2.05882029 | 14.69230442 | 13.72339165 | 2.09720171 | 12.83226347 | 13.74542090 | 13.74043567 |
| Decay Rate | -.00000239 | .00000098 | .00000024 | .00000217 | -.00000018 | .00000094 | .00000022 |
| Epoch Rev | 8335 | 55490 | 35390 | 4661 | 20775 | 17357 | 17286 |
| **Satellite** | **UO-14** | **AO-16** | **DO-17** | **WO-18** | **LO-19** | **UO-22** | **KO-23** |
| Catalog Number | 20437 | 20439 | 20440 | 20441 | 20442 | 21575 | 22077 |
| Epoch Time | 94198.24542996 | 94195.78079047 | 94199.72060632 | 94197.73736895 | 94196.24430425 | 94198.77455892 | 94198.40713031 |
| Element Set | 10 | 808 | 809 | 811 | 807 | 512 | 407 |
| Inclination | 98.5893 | 98.5977 | 98.5990 | 98.5989 | 98.5998 | 98.4336 | 66.0825 |
| RA of Node | 282.6137 | 281.4443 | 285.6692 | 283.7090 | 282.4984 | 272.6530 | 216.7082 |
| Eccentricity | 0.0011828 | 0.0012030 | 0.0012218 | 0.0012786 | 0.0013130 | 0.0007314 | 0.0015129 |
| Arg of Perigee | 100.6891 | 108.0022 | 96.2295 | 102.3306 | 106.5314 | 193.2332 | 279.4774 |
| Mean Anomaly | 259.5624 | 252.2471 | 264.0280 | 257.9303 | 253.7309 | 166.8641 | 80.4534 |
| Mean Motion | 14.29849660 | 14.29903339 | 14.30043483 | 14.30017383 | 14.30113337 | 14.36923567 | 12.86286995 |
| Decay Rate | .00000013 | .00000010 | .00000023 | .00000012 | -.00000013 | -.00000012 | -.00000037 |
| Epoch Rev | 23388 | 23354 | 23412 | 23384 | 23364 | 15747 | 9067 |
| **Satellite** | **AO-27** | **IO-26** | **KO-25** | **POSAT** | **MIR** | **NOAA-10** | **NOAA-11** |
| Catalog Number | 22825 | 22826 | 22830 | 22829 | 16609 | 16969 | 19531 |
| Epoch Time | 94198.16297797 | 94197.16066415 | 94197.23470784 | 94197.66078408 | 94199.14525698 | 94201.86328615 | 94201.84751066 |
| Element Set | 305 | 305 | 310 | 298 | 684 | 780 | 701 |
| Inclination | 98.6525 | 98.6521 | 98.5530 | 98.6462 | 51.6466 | 98.5077 | 99.1768 |
| RA of Node | 273.6702 | 272.7178 | 269.7323 | 273.2405 | 31.5281 | 209.8364 | 191.5874 |
| Eccentricity | 0.0009098 | 0.0009803 | 0.0012471 | 0.0010944 | 0.0001914 | 0.0012246 | 0.0012810 |
| Arg of Perigee | 116.6352 | 121.7855 | 90.3363 | 108.5827 | 139.9218 | 229.7166 | 40.6400 |
| Mean Anomaly | 243.5760 | 238.4287 | 269.9244 | 251.6545 | 220.1916 | 130.2942 | 319.5723 |
| Mean Motion | 14.27629544 | 14.27733649 | 14.28060091 | 14.28033511 | 15.56612283 | 14.24898582 | 14.13004374 |
| Decay Rate | .00000015 | .00000010 | .00000014 | .00000024 | .00005683 | .00000081 | .00000123 |
| Epoch Rev | 4196 | 4182 | 4184 | 4190 | 48084 | 40729 | 29989 |

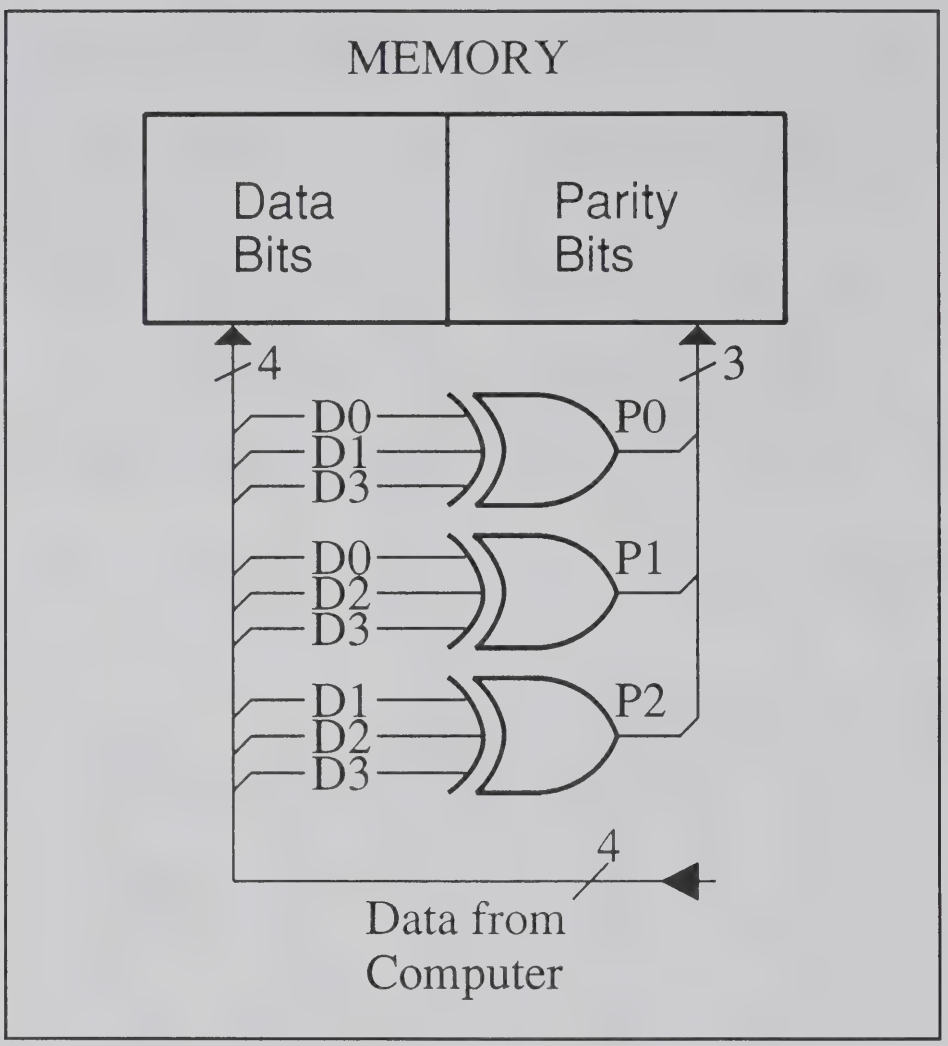


**Fig 1. The EDAC Write operation. The three parity bits are formed from exclusive-ORs of the data bits so 7 bits are written to memory.**

following, to keep explanations short, I'm going to assume initially 4-bit data words plus 3 parity bits, which needs a 7 bit wide memory word. (Oscar-13 itself has 4 parity bits, which can protect up to 11 data bits. However it uses only 8 of these, the other 3 being assumed "0".)

The WRITE operation is shown in Fig 1. The three parity bits are formed from exclusive-ORs of the data bits, viz P0=D0+D1+D3, P1=D0+D2+D3, P2=D1+D2+D3. Then these 7 bits (D0,D1,D2,D3,P0,P1,P2) are written into memory. They are collectively called a "code word". Since there are only 4 data bits there can only be 16 valid code words out the 128 possible 7 bit combinations. This 8-fold extravagance is what makes error control possible.

The READ operation is shown in Fig 2. The parity bits are calculated again from the 4 read data bits and compared with the 3 stored parity bits. Obviously both sets of parity bits should be the same, so the checks (marked S0, S1 S2) should all be 0. However if any one of the read 7 data+parity bits is in error, then one or more of the "S" bits will be set.

S0,S1 and S2 are aptly called the "syndrome" because they describe what is wrong with the data. The 3 bit syndrome is decoded in a 1 out of 8 decoder, and then one of these outputs corrects the erroneous bit.

To see how this magic works, consider the following table. It's a decoding matrix; the three across rows pick out the relationship between parity bits and data bits. The first row relates P0, and D0, D1, D3, the second P1 and D0, D2, D3, the third P2 and D1, D2, D3, just as indicated in Figs 1 and 2.

Turn the table on its side, and you should see some familiar patterns!

| | P0 | P1 | D0 | P2 | D1 | D2 | D3 |
|---|---|---|---|---|---|---|---|
| S0 | . | X | . | X | . | X | . | X |
| S1 | . | . | X | X | . | . | X | X |
| S2 | . | . | . | . | X | X | X | X |
| Q | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

Suppose for example that data bit D0 gets corrupted. From the "X"s in the table, the parity checks given by rows 1 and 2 (S0,S1) are going to fail, whilst S2 will be OK. Now S2=0, S1=1, S0=1 decodes as "3", which must mean "please correct data bit D0". Notice that all eight syndromes are uniquely associated with one corrupted bit. Formally, in terms of linear algebra, no one row can be formed by modulo-2 addition of any combination of the others.

However it is important to note that only one bit at a time can be corrected. If two bits are corrupted, then the wrong syndrome results. For example, suppose P0 and P1 are simultaneously in error, then the syndrome will be S2=0, S1=1, S0=1 which is "3" again, and obviously correcting bit D0 as before will only compound the errors.

Syndrome combination "0" means "no error", and is the usual condition. So its unexpected absence can be used to operate an error counter.

### AO-13's 8 bit Protection

As Oscar-13 has eight data bits, the simpler 4 data scheme described is merely extended by an additional parity bit. In principle therefore it's an 11 data + 4 parity system, but three data bits are not implemented, so it's 8+4 = 12 memory bits per byte. You should be able to see by inspection how the table is to be extended. By the way, this single bit error-correction scheme was invented by R.W. Hamming in 1950.

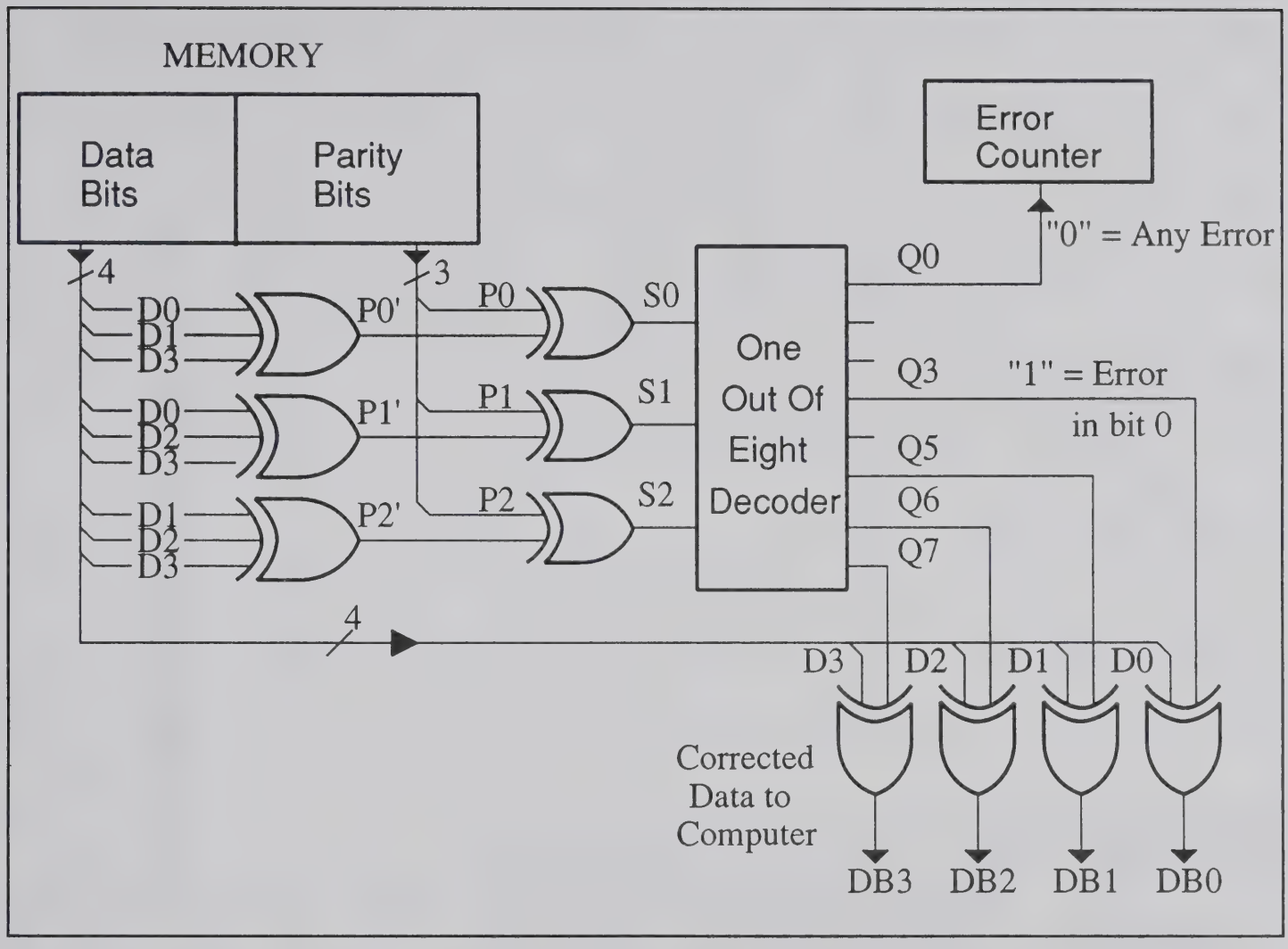


**Fig 2. The EDAC Read operation. The parity bits are re-calculated from the 4 read data bits and compared with the 3 stored parity bits.**

### AO-13 Performance

As mentioned earlier, when a memory bit is corrupted it is not only corrected, but a counter is also incremented and a block of telemetry is preserved for later analysis. From this data, charts can be drawn.

Fig 3 shows the number of memory errors that occurred in each 25 orbit segment up to 1994 May 13. The errors are very thinly distributed indeed. There are even two periods of zero hits in 4 months. In fact, since launch, 1988 Jun 15 to 1994 May 13 there were just 116 memory errors. That equates to an average of 1 error every 39 orbits. This is a remarkable testimony to the radiation resistance of the Oscar-13 memory system.

### Friday the 13th

After 1994 May 13 (a Friday), in the two months up to the time of writing 1994 July 12, things look rather different; see Fig 4. The memory error-rate has shot up by a factor of x>100 to an average of 3 per orbit!

In the week subsequent to May 13 the software on both LUSAT and ITAMSAT

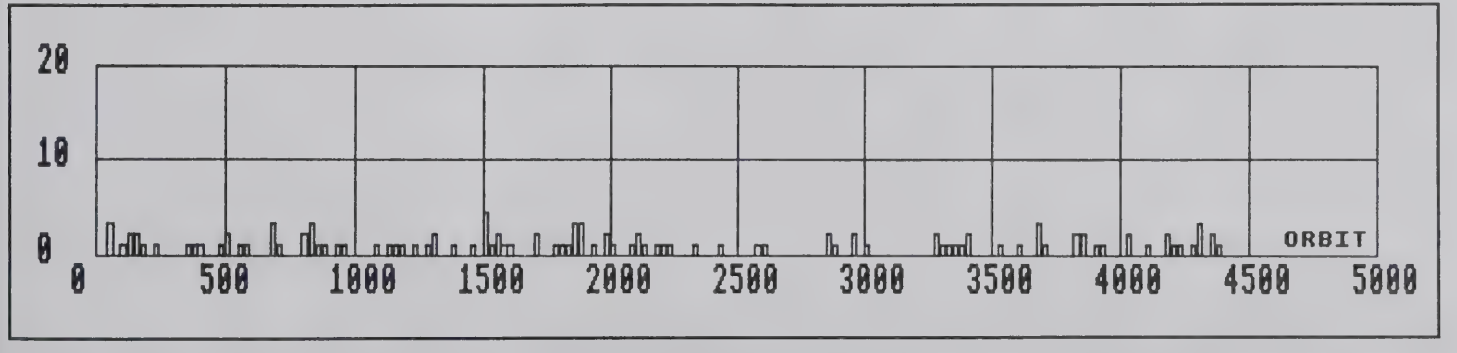


**Fig 3. Oscar-13 Memory Errors. The chart shows the number of memory errors that occurred in each 25 orbit segment from launch, 1988 Jun 15 up to 1994 May 13. In this period there were 116 memory errors, an average of 1 error every 39 orbits.**

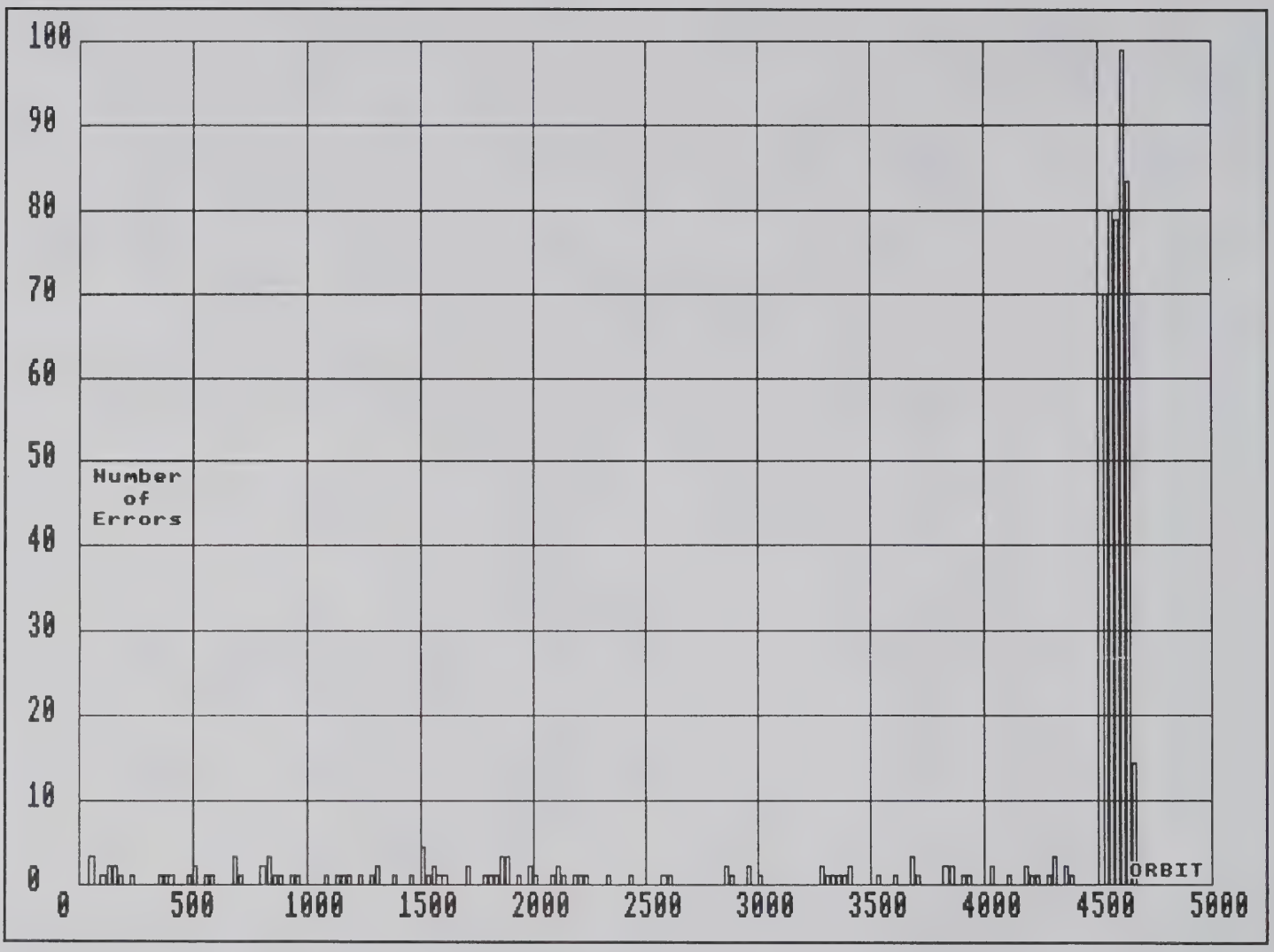


**Fig 4. Oscar-13 Memory Errors. In the two months from 1994 May 13 up to 1994 July 12, the memory error rate has shot up by a factor of x120 to an average of 3 per orbit!**

crashed, and KO-23 suffered a similar fate, though this may not be related. FO-20 digital mode has also run into problems, though again this may not be related.

Fig 5 shows a histogram of the number of orbits that have experienced 0,1,2 ... 9 hits. Superimposed in faint is a Poisson distribution with a mean of 3 events/orbit. A statistical test of their similarity confirms the hypothesis that the hits are random.

There is some evidence that the rate fluctuates slightly, as the number of hits per 25 orbit period (Fig 4) is a little too scattered for a steady rate.

### Conclusion

Well, what are we to make of all this? Has the radiation environment suddenly gone "over the top"? Has something deteriorated in the flight computer? Memory chips? EDAC circuits? In truth I am in no position to judge. I just press the buttons, and gather the telemetry. Explanations must come from the sages in these matters. In fact I have but one conclusion. It is this: "AMSAT has no potential Phase III command stations coming up through the ranks".

### Non sequitur?

OK, OK! How does he get from AO-13 increased memory errors to that ludicrous dogma? Simple. The memory error counter has been ramping away at over 100x the normal rate for two months. We have had more hits in those two months than we could have statistically expected in 20 years of normal operation.

Everything I have elucidated above is public knowledge. The principles of EDAC systems can be found in 1001 textbooks e.g. [1]. The description of AO-13's specific system is recorded in [2]. Solar flux data, warnings and analysis appear in prolific detail on all the digital networks. And finally AO-13 telemetry is available 24 hours a day for anyone to read.

Yet in these eight weeks, not one single person in the whole wide world has noticed or made any comment about the situation whatsoever!

Command stations are not made overnight. You don't take someone, plunk a manual (there isn't one!) in front of them, and at the end of a training period expect a fully fledged operator to emerge. It has never worked like that. This is Amateur Radio.

What actually happens is that interested people apply themselves, asking questions,

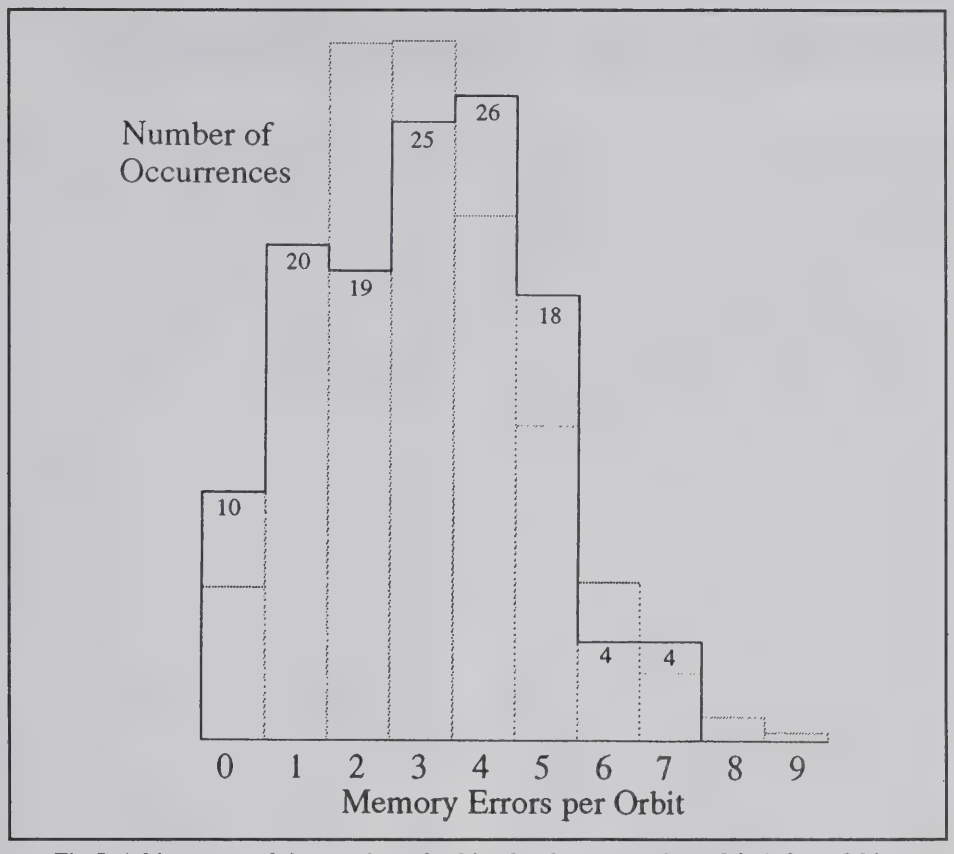


**Fig 5. A histogram of the number of orbits that have experienced 0, 1, 2 . . . 9 hits. Superimposed in faint is a Poisson distribution with a mean of 3 events/orbit.**

finding out answers and persevering, learning their craft almost imperceptibly, adopting a satellite as a rich source of intellectual and practical endeavor. This process can take as little as a year, but is often longer.

But the very act of doing this doesn't go unnoticed. If someone with these inclinations had come forward and asked even the simplest question like "why is this memory error counter racing away?", that in itself might just have been the seed from which a new command station could have been grown and nurtured to maturity.

But it didn't happen and, unlike a decade ago, it doesn't happen. Hence my conclusion; AMSAT has no potential Phase III command stations coming up through the ranks. What's the solution?

**References**

1. Haykin, S. "Digital Communications", John Wiley & Sons 1988. ISBN 0-471-62947-2.

2. Miller, J.R.; "Oscar-13 Memories are made of this", Oscar News 1989 Dec, No.80 p. 26-28

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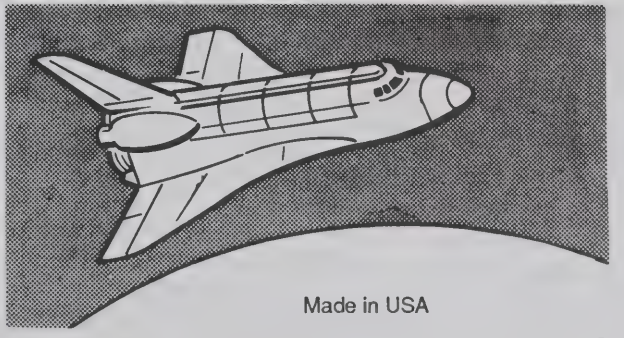

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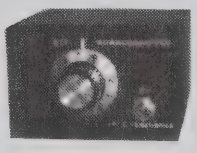

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# Doppler Shift Compensation in STSORBIT PLUS

*by Ken Ernandes, N2WWD and Dave Ransom*

## INTRODUCTION

A Doppler shift compensation display has been implemented in the STSORBIT PLUS satellite tracking software. Integration of Doppler information was a concerted effort by the authors of this article, with the intent of providing practical, but low-cost uplink and downlink frequency tuning information in real-time.

## DOPPLER SHIFT ISSUES

The Doppler effect is a frequency shift that occurs when there is relative motion between two stations. When the two stations are approaching each other, a signal sent by one of the stations will be perceived as having a higher frequency when received by the other station.

Likewise, when the two stations are moving away from each other, a signal sent by one of the stations will be perceived as having a lower frequency when received by the other station. This may be illustrated by the familiar scenario with the train whistle.

Perhaps the greatest challenge in low-altitude satellite communications is Doppler shift compensation, particularly with narrow bandwidth communications such as CW or SSB.

The Doppler shift problem is most challenging for low-altitude satellites because the Doppler frequency shift varies significantly in both magnitude and direction over the relatively short satellite overflight times. Furthermore, if the satellite is in a circular orbit, the rate of change of the Doppler shift is greatest around the time the satellite is at maximum elevation above the horizon, where the Doppler shift also reverses direction.

Compensation for Doppler shift requires the ground station to bias the tuning in one direction for the uplink and the other direction for the downlink. This is necessary so that the frequencies will be correct as perceived by the satellite on the uplink and the ground station on the downlink.

The problem is further complicated when a satellite is used as a crossband repeater for communication between two ground stations. In order for two stations to establish effective communications through a satellite, they must both coordinate their uplink and downlink frequencies. This is done by tuning their transmitters and receivers (with Doppler shift accounted for) to common frequencies with respect to the satellite. Since the Doppler shift is generally quite different for two stations a significant distance apart, both stations must individually coordinate their uplink and downlink tuning to remain in contact.

## DOPPLER SHIFT COMPUTATION

Computation of the Doppler-shifted frequency is a function of both the speed at which the satellite is moving toward or away from the ground station and the frequency being transmitted or received. The higher the relative speed, the greater the Doppler shift as a percentage of the original frequency. Likewise, the higher the frequency, the greater the Doppler shift in MHz (or whatever units are being used).

Determining the rate at which the satellite is moving toward or away from a station is primarily an orbit computation problem. STSORBIT PLUS uses the satellite's Keplerian elements and the US Space Command (USSPACECOM) Simplified General Perturbations Version 4 (SGP4) orbit propagation algorithm to compute the satellite's position and velocity for any given time. STSORBIT PLUS must also consider the fact that the ground station is also moving due to Earth rotation, called the Coriolis effect. The speed at which the station is moving depends on its latitude. STSORBIT PLUS integrates the Coriolis effect into the satellite velocity by treating the Earth as a stationary platform and transforming the satellite position and velocity to an Earth-fixed reference frame.

## STSORBIT PLUS DOPPLER IMPLEMENTATION

The Doppler implementation in STSORBIT PLUS was designed to accommodate both amateur radio satellite transponder equipment and typical ground-based amateur radio equipment. While the current implementation requires the transmitter (uplink) and receiver (downlink) tuning to be a manual process, the software user interface was designed to make Doppler compensation quick and relatively easy.

STSORBIT PLUS may be toggled in or out of the Doppler compensation mode by the F8 key. The Doppler compensation display uses the portion of the screen that normally displays both the Sun and the Tracking and Data Relay Satellite (TDRS) Acquisition of Signal (AOS) and Loss of Signal (LOS) event timers. The display lists: the uplink frequency (as perceived by the satellite), the corresponding frequency to which the transmitter should be tuned, the downlink frequency (as sent by the satellite), and the corresponding frequency to which the receiver should be tuned. The transmitter and receiver tuning frequencies are color-coded as follows: red when the satellite is below the geometric horizon, yellow when the satellite is less than five (5) degrees above the horizon, and green when the satellite is more than five (5) degrees above the horizon. The frequency display allows for frequencies up to 99999 MHz, and displays with a precision to the nearest 100 Hz.

The frequencies for the various Amateur Radio satellites are stored in the STSPLUS.FRQ text file. The records in this file are structured as: satellite number, uplink frequency, downlink frequency, and transponder mode (1 = normal; -1 = inverting). For satellites with frequency passbands, the uplink and downlink may be any corresponding frequency pair within these passbands. The STSPLUS.FRQ file may store up to ten (10) frequency records per satellite; each representing a different operating mode.

To accommodate satellites with frequency passbands, STSORBIT PLUS has a fast means of changing the frequency within the respective passbands. Passband frequency may be re-tuned in 1 kHz steps using the Page Up and Page Down keys and 100 Hz fine-tuning steps may be made with the Up and Down arrow keys. The "re-tuning" adjusts the downlink frequency; the corresponding uplink frequency is also adjusted (in the same direction for non-inverting transponders; in the opposite direction for inverting transponders). The appropriate transmitter and receiver (Doppler shifted) frequencies are re-computed automatically. The "re-tuning" is keyed to the downlink to facilitate answering another station's call heard in the downlink passband.

## TYPICAL SATELLITE DUPLEX CONTACT

For a typical contact using a satellite in crossband repeater mode, STSORBIT PLUS should have the uplink and downlink frequencies set near the center of the passband in which you plan to communicate. The receiver is then tuned through the passband until a signal is received. The received frequency is then set on the STSORBIT PLUS display using the PgUp, PgDn, Up arrow, and Down arrow keys so as to match the display with that received (downlink) frequency. When that is accomplished, STSORBIT PLUS immediately provides the transmit (uplink) frequency information for tuning the transmitter. To maintain the full duplex link throughout the contact, follow the transmit and receive recommendations on the STSORBIT PLUS display.

It should be noted that the above procedures presume that the other station in the contact is also maintaining a constant frequency set in the satellite's passbands. Since this presumption may not always be the case, you may need to re-tune the receiver to maintain contact with the other station. Once this is accomplished, follow the above to get STSORBIT PLUS to match your new downlink and provide the corresponding uplink tuning frequency. This entire process can be done with ease and generally requires only a few seconds.

## DOPPLER SHIFT ILLUSTRATION

To illustrate the difference in Doppler shift for two different ground stations, consider a postulated scenario in which the authors of this article would have a contact on the RS-10 satellite in Mode A from their respective homes in Stony Brook, NY and Rancho Palos Verdes, CA. The selected pass represents the real orbit of this spacecraft with mutual coverage of the two ground sites occurring on 09-Jun-94 from 11:47 to 11:58 UTC.

The RS-10 satellite in Mode A was chosen for illustration for three reasons: (1) this spacecraft is generally considered to be the best "starter" amateur satellite for the no-code Technician class license, (2) this satellite may be worked very effectively with a modest station, and (3) this satellite has the lowest (i.e., "best case") Doppler variation for low-altitude satellites within the bounds of the previous two qualifiers.

The Doppler shift for the two stations is not only different, but this difference also changes throughout the pass. Doppler shift is different because at any instant of time, the rate the satellite is moving toward (or away) from one of the stations is different from the rate corresponding to the other station. The differences in Doppler-shifted frequencies (uplink and downlink) versus time between the two stations are illustrated in Figure 1.

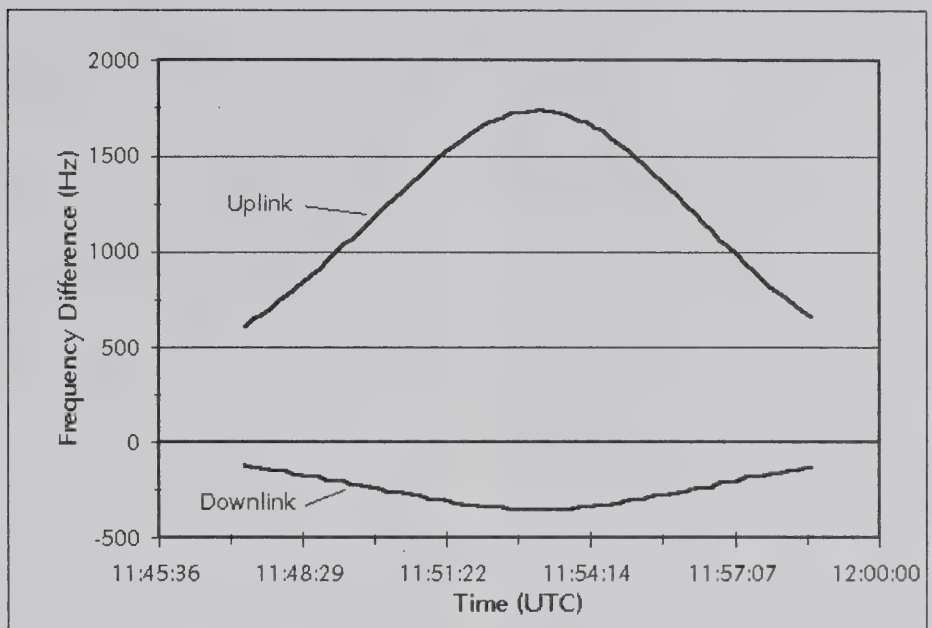



**Figure 1., RS-10 Doppler Frequency Difference for Palos Verdes versus Stony Brook.**

In this same example, the individual Doppler shifts for both stations are plotted individually for both uplink and downlink in Figure 2. Note that the uplink and downlink Doppler shifts cross-over at the Doppler zero points for each station. Since the orbit of RS-10 is circular, these zero Doppler points almost correspond to the times of maximum elevation for the respective stations. In this example, the times of maximum elevation are separated by three minutes. This is the main cause for the difference in Doppler shift between the two stations at any given time.

By this illustration, it is also clear that the 10 meter downlinks Doppler shift is about five times smaller in magnitude than

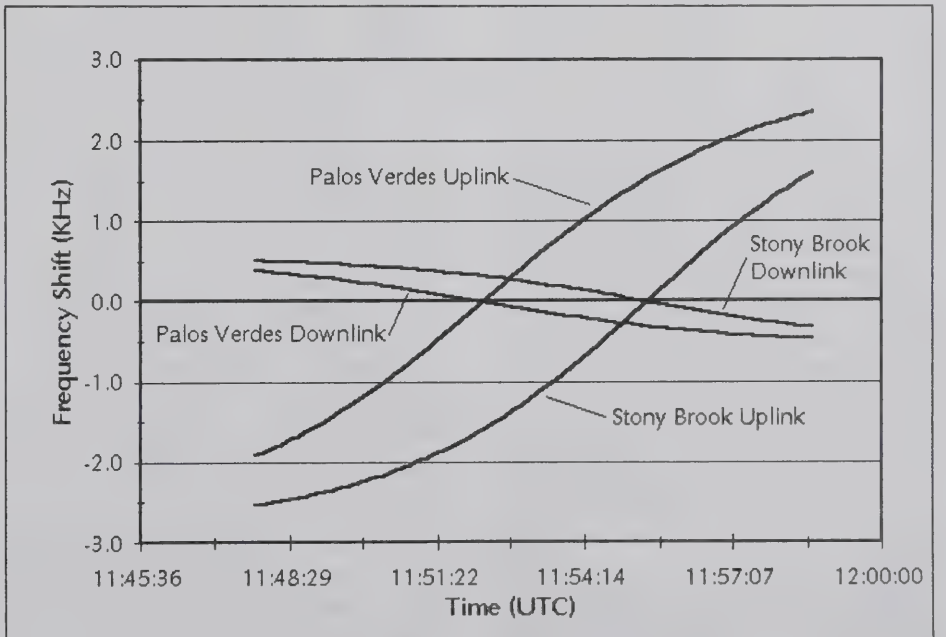



**Figure 2., RS-10 Doppler Shift Example for Palos Verdes versus Stony Brook.**

that for the 2 meter uplink. This leads to the practice of some stations maintaining a fixed downlink in Mode A and varying only the uplink frequency. When this practice is employed by one station on long-distance contacts, the other station must do "double duty," compensating for what results in drifting through the satellite's passband. The drift may result in interference with other contacts on adjacent frequencies in the satellite's passband, who are generally experiencing still different Doppler shifts.

Since the Doppler shift has different values at different times for different stations, the varying frequency drift rates are a significant cause for adjacent frequency interference.

Therefore and particularly when the satellite passband is crowded, the authors recommend adjustment of both the uplink and downlink frequencies to maintain a constant pair of frequencies with respect to the satellite.

## TESTING AND VALIDATION

The primary testing of the STSORBIT PLUS Doppler compensation was accomplished on RS-10 in Mode A, using the center of the voice passbands as the uplink and downlink frequencies in the STSPLUS.FRQ file. One of the authors of this article (N2WWD) did some preliminary testing with a rather modest setup that included an ICOM IC-211 (10 W) through a Discone on the uplink and a Kenwood R-1000 through a 10 m Cushcraft Ringo on the downlink. The Kenwood R-1000 was known to have an approximately +2 kHz bias on the displayed frequency, so this needed to be taken into account.

The first test was accomplished on RS-10 on a pass over the Atlantic Ocean that had only a 7-deg maximum elevation. A weak and noisy full duplex link was established and the frequencies remained at a steady 3 kHz difference from that indicated on the STSORBIT PLUS display. Because of the known 2 kHz bias in the Kenwood's display and the accuracy of that receiver's display being only to the nearest kHz, the conclusion was that the first test was a success. (It was not realized at the time that the 3 kHz difference was in the wrong direction.)

For the next series of tests, the +2 kHz bias was accounted for in the STSPLUS.FRQ file. In this series of tests, the transmit frequency required to establish a full duplex link was surprisingly about 5 KHz higher than that indicated by the STSORBIT PLUS display. After some additional data gathering, it was found that if a -3 kHz bias (rather than +2 kHz from the center of the passband) was placed on the downlink frequency in the STSPLUS.FRQ file, that the Doppler display accurately determined a Doppler-compensated set of uplink and downlink frequencies. This was verified throughout multiple passes, each with significantly different geometry.

The unexplained frequency bias was cause for a second opinion. The services of John Gordon (KD2JF) were thus obtained to perform independent testing on RS-10. The result of these tests was that KD2JF found the uplink frequency to establish a full duplex link on RS-10 was about 5 kHz higher than that indicated by the STSORBIT PLUS display. Because of the independent agreement of the results, the STSPLUS.FRQ file was modified by subtracting 5 KHz from the downlink center passband frequency of RS-10.

Testing was also performed by monitoring the downlink of the Russian Mir Space station. The observed Doppler shift for this satellite agreed very closely with that predicted by STSORBIT PLUS. The conclusion from these test results is that the published frequency is correct for Mir. Additionally, KD2JF performed some testing on AO-13. He found the downlink passband to have a 2 kHz translation bias from the published information. It was therefore concluded that the published frequencies (as presumably supplied by the spacecraft designers) do not necessarily match what the spacecraft is actually using.

The translation biases for AO-13 and RS-10 were independently confirmed thanks to the work of John Hansen (WA0PTV), Buzz Gorsky (WH6I), and Walt Daniel (KE3HP). The chart "Current Amateur Satellite Frequencies" on page 22 of the March/April 1994 (Volume 17, No. 2) Edition of the AMSAT Journal provides frequencies for the amateur satellites without Doppler compensation. Therefore, the STSPLUS.FRQ file was updated to reflect the frequencies in this table.

Since the publication of the frequency table, we received a report from Dean Norris (K7NO) and Nicholas Sues (W7ZMD) indicating an 800-900 Hz translation bias on the downlink of RS-12. They have recommended setting Mode K frequencies of 21.2300 MHz for the uplink and 29.4308 MHz for the downlink for RS-12 in the STSPLUS.FRQ file.

## SOURCES OF ERROR

The accuracy of the STSORBIT PLUS Doppler compensation is limited mainly by the accuracy of the inputs including: the Keplerian elements, the real-time computer clock, the frequencies in the STSPLUS.FRQ file, and the ground station location. Since the transmitter and receiver are an integral part of the system, the possibility of error and/or biases in their frequency displays must also be considered.

## ACCURACY OF KEPLERIAN ELEMENTS

Generally, the more current the Keplerian elements are, the more accurate will be the computed satellite positions and velocities. Generally, the first sign of degraded predictions by the Keplerian elements will appear in the Doppler shift. A bias of several hundred Hz is evident in the STSORBIT PLUS Doppler display when the prediction accuracy of the Keplerian elements begins to deteriorate. Because Doppler shift is proportional to frequency, the higher the satellite's operating frequencies, the more sensitive the Doppler shift will be to even small prediction errors in the Keplerian elements.

The rate at which prediction accuracy deteriorates for Keplerian elements depends mainly on the orbit, the magnitude (and change) of the drag effects, and the magnitude of third body (Sun, Moon, Planets) gravitational attraction. Any comprehensive formula to predict time-perishability of Keplerian elements would be very complex and beyond the scope of this article. As a practical matter, however, use the following table as a rule of thumb:

| Average Altitude (Kilometers) | Mean Motion (rev/day) | Update Frequency (days) |
|---|---|---|
| < 300 | 15.9 or more | at least every other day |
| 300 - 500 | 15.9 - 15.2 | 2 - 5 |
| 500 - 1500 | 15.2 - 12.4 | 5 - 14 |
| > 1500 | 12.4 or less | 14 - 30 |

**Table 1. Recommended Keplerian Element Update Frequencies**

The rule of thumb for Keplerian element updates is based on the typical drag and third body effects for satellites in the corresponding altitude bands and accounts for the ability of SGP4 to reasonably compensate for these effects. It is not unusual for some errors in the Doppler shift to appear near the end of the recommended update interval.

Since SGP4 presumes constant drag, any substantial change in the upper atmospheric density will result in a rapid deterioration of the Keplerian elements' ability to accurately predict the satellite's positions and velocities. Since the upper atmospheric density becomes heated rapidly by events coinciding with increases in the 10.7 cm solar flux, this is the primary indicator. Therefore, any significant change in the 10.7 cm solar flux level between the epoch time of the Keplerian elements and the present time is sufficient cause to replace the Keplerian elements.

Furthermore, the rule of thumb cannot be applied when a satellite maneuvers; new Keplerian elements should be obtained as soon as practical following a maneuver. For example, Mir and the Space Shuttle perform frequent and sometimes radical maneuvers that change the orbit substantially. Once a maneuver occurs, the ability of pre-maneuver Keplerian elements to predict the satellite's future positions and velocities deteriorates very rapidly, usually in a matter of hours.

## ACCURACY OF COMPUTER CLOCK

Since the Doppler shift changes rapidly during the pass of a low altitude satellite, the real-time computer clock should be set as accurately as possible. A clock accuracy within one second of the "truth" has been found to be quite adequate. The time may be set within STSORBIT PLUS by synchronizing to the National Institute of Standards and Technology (NIST) WWV or WWVH (2.5, 5.0, 10.0, 15.0, or 20.0 MHz). Alternatively, these stations may be contacted by telephone at 303-499-7111 for WWV and 808-335-4363 for WWVH.

There are a number of shareware and commercial programs that can synchronize your computer clock very precisely through a modem with the NIST or the Naval Observatory in Alexandria, Virginia. Computer programs are also available to maintain the computer clock's accuracy between time sets, thereby reducing the need to call a time service as frequently.

## ACCURACY OF STATION COORDINATES

The need for reasonably accurate ground station coordinates is important for Doppler computation. While the location of a nearby city in the STSORBIT PLUS city (STSPLUS.CTY) file usually provides a good starting point, better Doppler results are obtained when the coordinates of your station are provided to the software. For best Doppler results, we recommend adding your station coordinates as a custom entry in the STSORBIT PLUS city file.

Reasonably accurate station coordinates may be estimated (interpolated) from good quality maps that include fiducial marks or grids (any marks, cross hairs, or lines that indicate known latitude and longitude). This technique has been employed using high quality US Geological Survey (USGS) topographic maps. Later position confirmations using a Global Positioning System (GPS) receiver indicated this method has a typical accuracy within five hundred meters of the average GPS position determination.

## CONCLUSION AND FUTURE DIRECTIONS

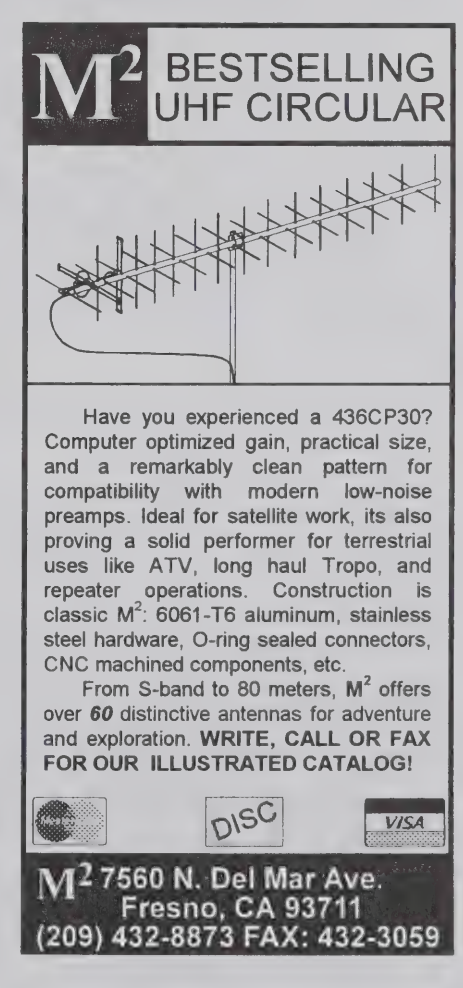
The original intent of STSORBIT PLUS (and its predecessor program, STSORBIT) was to provide an accurate numerical and graphical display for the orbit of any satellite for which Keplerian orbital elements (Two-Line Elements or "TLEs") were available. The plan was to duplicate and, if possible, improve upon the wall display at the Johnson Space Center (JSC) Mission Control Center. It was hoped that this would be of interest to the general public and particularly in education, encouraging greater awareness of computers, science, and the space program.

To say that this "plan" has been successful would be understating the case considerably. One of us (Dave), has been all but overwhelmed by the response to the program, far exceeding his most optimistic expectations. Unexpectedly, because he is not an amateur radio operator and was unaware of the extent to which amateur radio utilized satellite transponders, some of the most enthusiastic responses have come from the amateur radio community. As a result and in close collaboration with N2WWD (Ken), the performance of STSORBIT PLUS has been enhanced and special features directed specifically toward amateur radio have been added. The latest and most prominent of these are the Doppler Shift features, the subject of this article.

N2WWD (Ken), with assistance from other amateur radio colleagues, has performed testing and validation of the Doppler compensation function using various satellite transponders.

With only a few surprises, the concept proved out well in practice right from the very start. The program has now been released with the new Doppler Shift features, and encouraging reports are being received from other users.

To our surprise and pleasure, even those features intended primarily for amateur radio have been eagerly embraced by other users, ranging from NASA Centers and the USAF to educators, students, and "just plain folks" worldwide. The software has been seen on television both in the United States and internationally, and has been used operationally on at least two Space Shuttle missions. Participants in the Shuttle Amateur Radio Experiment (SAREX), notably at Telebridge Centers such as the one in Honolulu, Hawaii, are regular users of the program.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Obtaining and distributing accurate orbital data has also been a major project for both of us over the past year. A key ingredient in this process is VEC2TLE, written by N2WWD (Ken) for this project. This software converts orbital state vectors (the form in which orbital data is most easily obtained from NASA and other satellite operators) to Keplerian Elements for use with STSORBIT PLUS and other satellite tracking programs. Using VEC2TLE and with the cooperation of individuals at several NASA/USAF agencies, we were able to generate Keplerian TLEs in near real time; these TLEs have been validated over some five successive Space Shuttle missions. These data, combined with the amateur radio satellite TLEs available from several public sources (below), have facilitated many a satellite contact.

Both of us have dedicated considerable time and effort to help make the programs and data more readily available. We believe more should be done to better interconnect both the excellent radio (packet) and BBS sources for faster distribution of (particularly) the real time data. Individuals or groups interested in participating are invited to contact the authors.

One of us (Dave) operates the RPV Astronomy BBS in Rancho Palos Verdes, California. The other (N2WWD, Ken) is Co-Sysop on the Ham-It-Up (an AMSAT Network BBS) on Long Island, New York. Both of us regularly post orbital data in the HamNet, Astronomy, and Space Forums on CompuServe as well. We may be contacted at the following E-Mail addresses:

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[Internet] 70511.3107@compuserve.com or 70511.3107@cis.com

[Packet] N2WWD @N2BQF.#NLI.NY.USA.NOAM

**Dave Ransom**

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[Internet] 75240.176@compuserve.com or 75240.176@cis.com

Except as otherwise noted, the BBSs in Table 2 are free systems available to the public.

STSORBIT PLUS is an MS-DOS program available for $20 from AMSAT-NA.

| BBS Name | Telephone # | Baud Rate |
|---|---|---|
| RPV Astronomy BBS (2 lines) | (310) 541-7299 | 2400-14400 |
| Ham-It-Up BBS (2 lines) | (516) 878-4906 | 2400-14400 |
| NASA OIG RAID RBBS* (4 lines) | (301) 262-6784 | 1200-2400 |
| NASA Spacelink BBS (8 lines) | (205) 895-0028 | 1200-9600 |
| Celestial BBS | (513) 253-9767 | 1200-9600 |

* Requires pre-registration by mail

**Table 2. Non-Commercial Electronic BBSs With Orbital Information**

## REFERENCES

[1] The Satellite Experimenter's Handbook, Martin Davidoff (K2UBC), ARRL, Copyright 1990.

[2] How To Use The Amateur Radio Satellites, Third Edition, Keith C. Baker (KB1SF), Copyright 1992.

[3] Fundamentals of Astrodynamics, Roger R. Bate et al., Dover Publications, Inc., Copyright 1971.

[4] Project Space Track, Models for Propagation of NORAD Element Sets, Spacetrack Report No. 3, Felix R. Hoots and Ronald L. Roerich, Aerospace Defense Center ADC/DO6, 1980.

[5] Current Amateur Satellite Frequencies, John Hansen (WA0PTV) et al., The AMSAT Journal, Volume 17 No. 2, p. 22, AMSAT-NA, March/April 1994.

[6] "At the Tone...", Steve Ford (WB8IMY), QST, pp. 62-63, ARRL, June 1994.

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3335 PA 10 in 40w out 900- 930 MHz $330
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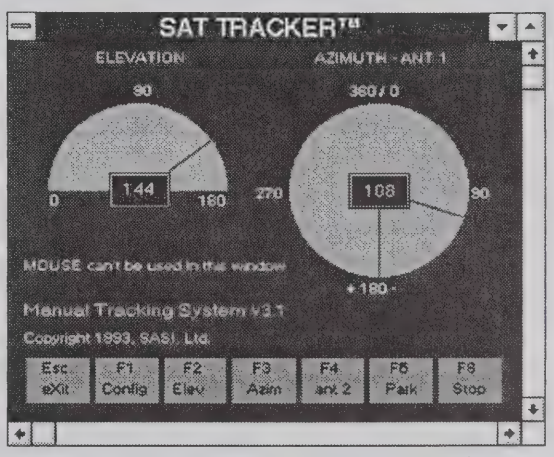


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# 1994 AMSAT Field Day Competition Results

*by Andy MacAllister, WA5ZIB*
*14714 Knights Way Drive*
*Houston, Texas 77083*

The 1994 AMSAT Field Day Competition was held in conjunction with the yearly ARRL Field Day in June. Rules for the AMSAT activity were very similar to those posted by the ARRL with a few key exceptions. While the ARRL rules provide bonus points for certain activities, the AMSAT rules do not. The AMSAT rules call for each satellite to be considered as a separate band, while the ARRL rules currently do not. Special provisions were also included in the AMSAT rules to allow points for uploading and downloading Field Day greeting messages via the digital satellites. Next year digital uploads and downloads will be worth five points each and each transponder on each satellite will be counted as a separate band in addition to the CW/Phone band distinction. Some modifications to the reporting sheet will also be made to provide more room for satellites and modes, provide a line for group or club name and a box for total claimed score.

The 1994 competition was extremely active. Every available satellite over North America had Field Day participants in hot pursuit of contacts. No reports of loading problems on the birds were noted. Almost twice as many reports were received this year and with some very good scores. Of the 34 submissions, there were two ties at places 17 and 29. The Scottsdale Amateur Radio Club working with the Central Arizona DX Club came in first with 377 points. They operated on RS-10, RS-12, AO-10, AO-13, FO-20, AO-21 and AO-27. Ned AA7A was the chief satellite operator and Bob W1XT was Field Day Chairman. They have certainly set a new high score. Next year promises to be a great event. Plan now to get your club or group ready for Field Day satellite activity. The results for 1994 follow:

**Comments from Participants:**

**Jim Mollica, N2NRD comments on the individual satellites:**

AO-27: Very sensitive and easily overloaded. Super sigs and audio.

AO-21: Not as sensitive as 27 but equal signals and audio. Both 27 and 21 were getting hammered with strong uplink signals from stations trying to capture the transponder. There is enough pass time to spread the calls out and run the QSO totals up on these birds.

FO-20: Performed fantastically. Excellent signals and QSO run.

RS-10: Much time spent listening through stations trying to find their downlink.

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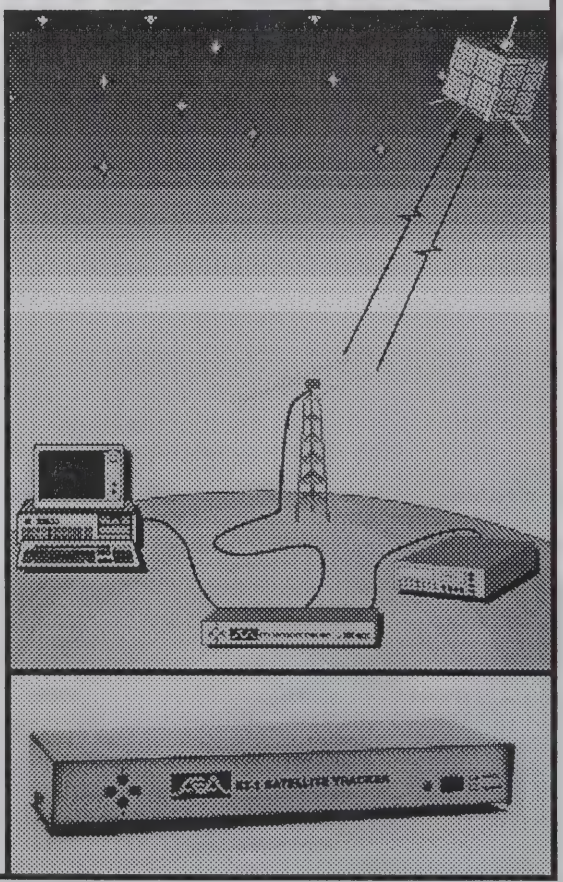

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AO-10: OSCAR 10 was the best I have heard it in years. At apogee the signals were strong with very little fade. Perigee had 10 pass over at high elevation with very strong signals making for a good QSO run.

AO-13: The pointing angle on OSCAR 13 was not favorable for FD this year. The transponder sounded very loaded down.

The ability to switch polarity was a big plus on all the birds.

Plans for next year:

Operate the same antenna setup from a location with an excellent view of the horizon in all directions.

Spend more time operating CW.

Get on the digital birds. (ed. note: These guys came in 2nd without operating the digital birds at all. What does this tell us?)

**Bob Walker at the N4CU operation:**

AO-10 seemed to lose power after an hour. No one else said the same thing so we must have just had the antennas pointed wrong. No problems with AO-13 using Mode B. Same Mode S equipment that worked at home did not work on Field Day. We could not even hear the beacon. This was the first year we tried RS's and Pacsats. We could have made more contacts by staying on 13, but got great experience using the LEO's. Need info on emergency use of satellites to justify cost of equipment for EOC to county. We had a joint RACES/ARPSC exercise where county officials came out to watch. They were mostly impressed by the fast-scan TV. Satellites appear to have no communications path out of a disaster area. Who provides the link to FEMA?

**Albert NX2Q for the W2OZU/NX2Q team:**

Our young visitors almost took over my camper satellite station. They must have enjoyed themselves. We certainly did.

**Christie Harper KD4QIO (operating K4BFT):**

Murphy was one of our operators this year. We had all sorts of problems and were not able to work any of the LEO satellites. The system took about 40 minutes to set up and included a Yaesu FT-736R, Mirage D1010, 2-meter Landwehr preamp, 5400B rotator, TAPR Trakbox and a 2 x 12 element 70-cm, vertically polarized Yagi array.

**Vince Fiscus KB7ADL (operating K7EFA):**

We really enjoyed satellite operation this year and contacted a lot of other fine stations and operators! We hope to work all again next year. Thanks to AMSAT for sponsoring this part of Field Day.

**WM5U with the Lockheed Radio Club:**

At first glance, one would have thought that satellite availability would have really kept the scores down this year. But AO-10 really did a fine job and AO-13 worked fairly well even at the relatively high pointing angles.

We pointed the antennas at the sun and aligned them using the antennas' shadows on the ground. By the way, we also experimented with a conductive (aluminum) elevation mast as described in Kent Britain's article published in the 1993 Symposium Proceedings. Just from cursory observations on FD, it looks like this arrangement should work just fine. The only notable problem observed with this arrangement is some enhanced desense as compared to a non-conductive elevation mast with equal antenna separation.

**Lee Copeland N4TM (operating W4IZ):**

50 mph winds and an inch of rain in less than an hour at 3 PM Saturday - with an encore of storms at 4 AM Sunday. Will participate again next year.

**Jim Huhta AA4MD (operating K3OPE):**

Bob's Mob from the "Bob" repeater (73 Wilmington) was 2A Eastern Pennsylvania. Thank God for the low-orbit satellites! Our first effort on those and very hectic. Even with rotators it was a three-person job to stay aimed.

**Ron Hall at KP2N in the Virgin Islands:**

Think this is a first for the VIARC. First time in AMSAT Field Day competition, and maybe our first ever entry for

**Ned Stearns, AA7A, operated the K7TR Field Day satellite station for a total of 377 points. A Yaesu FT-726R was the main satellite radio. Automatic antenna tracking was done with a SASI Sat Tracker and a very old laptop computer. His antennas were single CP Yagis for 2 meters and 70 cm, an SB-32 for Mode S, a CP loop for 10 meters and a 3 element Yagi for 15 meters. Says Ned, "I probably won't setup for RS-12 next year. Everything else worked great. Lots of fun!" (Photo by Bob Myers, W1XT)**

the U.S. Virgin Islands. In 1992 we had one contact, in 1993 we managed 19. This year we went all out and got 76. We were at 1200 feet overlooking Charlotte Amalie with almost a 360-degree view. Were able to track most satellites to LOS. Wish AO-13 had been magnetorqued before Field Day. A good time was had by all and looking forward to next year.

**Alan Arrison KB2AYU (operating W2MMD):**

Overall conditions were poor. AO-13 was again in a poor attitude. The "FM" birds were mayhem. The digital birds should be worth 3 or even 4 points to encourage more use and to reward those who take the time and effort to work them.

**Thomas Cash K4ZQX (operating W4AM):**

We had some electrical storms and plenty of rain but in the short time we worked (on Sunday mainly) we worked every station we heard.

**Tom N0NTX at the WA0VTU operation:**

AO-13 was much better this year! I should have brought my Mode S equipment for the last hour. It would be nice to have logging software that would be compatible with CT and allow us to log by satellite.

**John, N2WM:**

The competition was great, the birds saw a lot of activity. AO-10 sounded better than AO-13, and the FM birds were mobbed. Last year I wrote a letter to the ARRL hoping to convince them to revise the FD rules to be more in step with the AMSAT rules. Obviously it didn't change things.

**Roger Wiechman at N6DD/7**

We tried doing RS-12 but it turns out the two or three contacts made were 15 meters direct. The wind god seemed to have the same ephemeris tables we had generated for tracking. Just about AOS for most of the LEO passes, the winds increased from 5-10 mph to 25-30 mph and lasted for 20 minutes. This raised havoc with our armstrong rotator system. There were times when we thought the 736 would be blown off the table! Temperatures for the weekend peaked at 119.7 F. But not to worry, its dry heat!! It did cool down to 95 at night though...

| Place | Call | Points | Group Name |
|---|---|---|---|
| 1 | K7TR | 377 | Scottsdale ARC & Central AZ DX Club |
| 2 | N2NRD | 284 | James Mollica |
| 3 | N4CU | 182 | Bob Walker & Crew |
| 4 | NX2Q | 173 | W2OZU & NX2Q |
| 5 | WB6LLO | 161 | Dave Guimont & Crew |
| 6 | K4BFT | 152 | Huntsville ARC |
| 7 | K7EFA | 151 | Yellowstone Radio Club |
| 8 | W5SC | 140 | San Antonio Radio Club |
| 9 | WM5U | 127 | Lockheed Radio Club |
| 10 | W4IZ | 125 | North Florida ARS |
| 11 | KK5W | 115 | Brazos Valley ARC |
| 12 | K3OPE | 113 | Bob's Mob |
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| 19 | N2WM | 83 | John Santillo & Crew |
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| 26 | KI6PR | 59 | Michael Siegel & Crew |
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| 29 | KN4RY | 41 | Port St. Lucie Amateur Radio Assoc. |
| 29 | VE8EV | 41 | John Boudreau & Crew |
| 30 | W4ABR | 18 | Johnson City Radio Association |
| 31 | N8NAV | 15 | Club Edison Radio Amateur's Assoc. |
| 32 | W6RGG | 3 | Robert Vallio & Crew |

**Joe Mayfield KA0YOS (operating W0TWU):**

Not working FO-20 hurt us bad. We used equipment from several stations and ran into a desense problem. This was perhaps a lesson in favor of testing your setup before Field Day? We probably should have utilized RS-10 better. AO-10 was fabulous!! Where did everyone go when it came back out of eclipse? Next year we are going to work Mode S too.

**Vick Applegate WA7DEO (operating KC7HP):**

The Hellgate Amateur Radio Club operated using emergency power from a site on the Lolo National Forest near Missoula, Montana. Thanks for having this contest. A lot of interest was generated by our satellite station even though the satellites were less frequent than in previous years.

**Dave Haben KA3VGD (operating N3KR):**

I had a great time with it even though I had to get up at 2 AM Sunday morning to work AO-10 and AO-13 an hour or so later! Too much beer on Saturday made it difficult!

I was amazed at the 1.5 Hz spin modulation frequency on AO-10 as the pass progressed. It was quite difficult to speak or send CW with the correct spacing so that the downlink signal would peak at the right time!

It was disappointing to find out that the Mode B transponder on AO-13 was switched off until MA 080 or so even though the B beacon was S6 or better. This information was not available anywhere that I knew of. These surprises should be put into the AMSAT bulletins from the Internet/CompuServe (especially before an event like Field Day). I ended up being told this information by one of the contacts I made on AO-10!

**Dave Jones WB2YLR (operating K2CT):**

The satellite station was busy all day with visitors. They all were fascinated by its capabilities. Demonstrating the station left little time to operate.

**Roger Snyder, KC4NHB at KN4RY submitted his journal from FD:**

... The next 18 hours are pure frustration. There are lots of stations on AO-21, but we can not access the bird. No luck on RS-10. One contact on RS-12 and one contact on FO-20. I can't wait for AOS on OSCAR 13. The local press and TV have given us a lot of coverage. LOTS of people come by to see the satellite station in operation, including a couple of reporters. Finally AO-13 comes over the horizon. The beacon is strong, but I can't find my downlink! No one else is on the bird either. I copy the CW from the beacon and realize that there has been a change in the transponder schedule. In desperation I try AO-10. I manage to work 9 stations. Not too bad for a "dead" bird. ...

**John Boudreau operating VE8EV from Inuvik, NWT, Canada:**

A late arrival at the Field Day site and a bad connector on a feedline delayed the start of operations until after 2300 UTC. The LEO satellites were completely jammed over the continental U.S. but did offer opportunities for a few contacts on the fringes and also from Alaska and over the pole to Europe. AO-10 was in good condition for this exercise and although weak and noisy, it allowed for solid contacts while it was up. I was copying the AO-13 beacon at S-9 when it first came up early Sunday morning but by the time it became active it was still too far off-pointed and went below the horizon before a single contact could be made. Software problems kept me off the Pacsats for the duration. Conditions on HF were very


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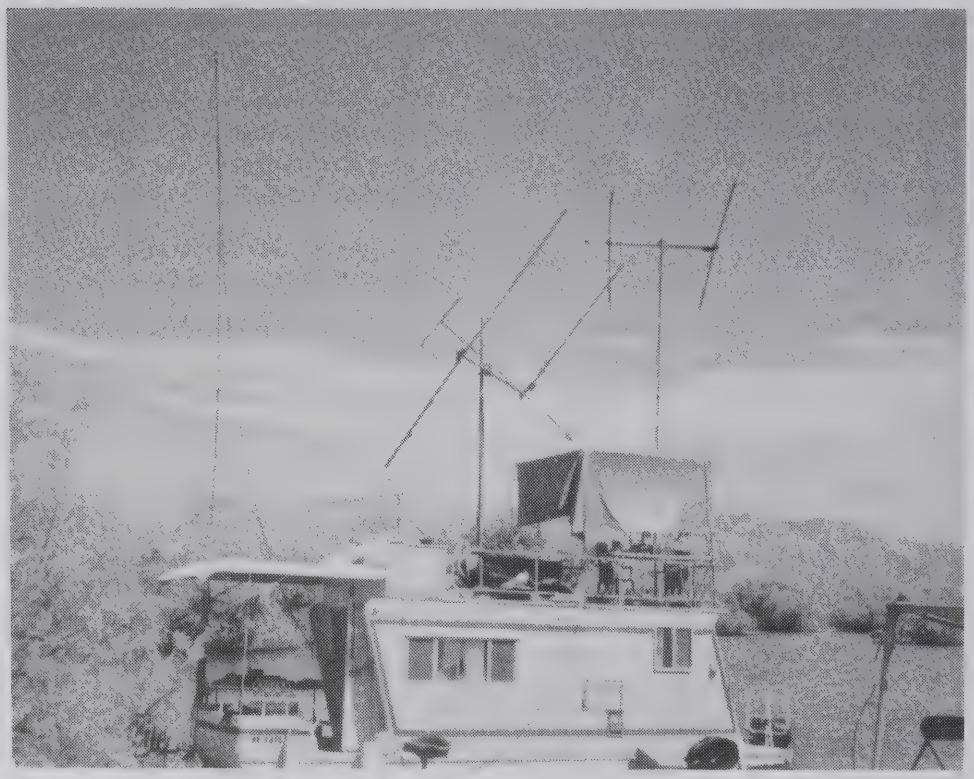
poor here and the satellites more than proved their value for allowing reliable communications under any conditions.

**Greg, KB4NVD for the W4ABR operation:**

The UARC has it's satellite station set up on what we call an "OSCART". We have a Ten-Tec Argosy II with a Ten-Tec 2510 Mode B satellite station sitting on the shelf of a cart. The az-el rotator is a KenPro mounted on a short piece of mast that is at one end of the cart. A set of Cushcraft antennas round out the OSCART. This makes for a pretty handy and portable setup. FD '94 was definitely a learning experience for the club. We had two members make their first satellite QSO's that day. Talk about getting the club fired up! We may not have burned up the AMSAT FD contest, but we are motivated and learning.

**John Sheets N8QGC (operating N8NAV):**

We used an oversized camera tripod to hold the antennas. On two meters we used a KLM 14-C and on 70 cm we used a KLM 6X which normally use to work AO-21 and AO-27 Mobile. The rig was a Kenwood TS-790A and we had an RF Concepts 170-Watt, two-meter amplifier to help us out. The antennas were turned by a ham who would stand at the tripod. The effort was coordinated by another ham who would stand over my shoulder and by HT tell him where to point. All and all it worked out just fine. Our best contact came on FO-20 at 0811 UTC when we worked KP2N in the Virgin Islands. I'm sure we broke no records but we had a lot of fun. Look out next year, we're going to have a full-blown satellite station. The crew included: John Sheets N8QGC in charge of overall operations and radio operator, Mike Clark N8WAH the antenna position coordinator, Brian Westphal KB8QXA as the first human antenna rotator, Bill Coury N8UUP as the second human antenna rotator and Joe Hampton KB8HGL as the third human antenna rotator. The popular joke at our Field Day was that it took eight people to run the satellite station, but boy were they productive!



**Dennis Dinga N6DD/7 operating houseboat mobile on the Colorado river (Lake Mohave) about 60 miles SW of Las Vegas.**


## AMSAT Publications

**Satellite Experimenters Handbook:**
*By: Marty Davidoff, K2UBC*
A must for every Satellite enthusiast's bookshelf. Covers; history, fundementals of station construction, tracking as well as advanced topics. $23/25/30

**PACSAT Beginner's Guide:**
*By Mike Crisler, N4IFD*
Step by step instructions to becoming PACSAT-active. $12/13/15

**Beginners Guide to AO-13:**
*By Keith Bergland, WB5ZDP*
Step by step instructions to becoming active on OSCAR 13. $7/8/10

**Beginners Guide to the RS Satellites:**
*By Gould Smith, WA4SXM*
Step by step instructions to becoming active on the RS Satellites. $7/8/10

**Decoding Telemetry from the Amateur Satellites:**
*By Gould Smith, WA4SXM*
Describes the telemetry systems of each of the current Amateur Satellites - thru AO-21 and RS12/13. $15/19/25

**Weather Satellites Handbook:**
*By Ralph Taggart, WB8DQT*
Describes the how-to's of receiving commercial weather satellite images on "ham accessable" equipment. Similar in scope to the Satellite Experimenter's Handbook. $23/25/30/35

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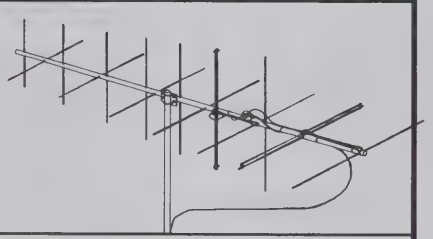

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Prepared by Bruce Paige, KB5ZRV

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**Oscar Sexagesimal Award**

1 Satellite Contact with 60 Different U.S. or VE call areas or DXCC countries

**Oscar Century Award**

1 Satellite Contact with 100 Different U.S. or VE call areas or DXCC countries

**South Africa AMSAT Satellite Communication Achievement Award**

25 Satellite Contacts on any Phase II satellite only (example FO-20, AO-21 & 27, RS-10 & 12)

For all above awards — Send: Xerox of front/back of QSL Cards — To: AMSAT Awards Manager
Mike Scarcella, WA5TWT
310 Lombardy
Sugar Land, TX 77478

Cost: $3.50 AMSAT Members, $5.00 Non-Members. Both add 2 units postage.
Note: Alaska and Hawaii may only count as a state not as a DXCC country for AMSAT Awards.

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**K2ZRO Memorial Station Engineering Award**

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Levels 0-9 & A

Andy MacAllister, WA5ZIB
14714 Knightsway Dr.
Houston, TX 77083

Fee only required for initial certificate. Endorsements add 1 unit postage.
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**W4AMI Satellite Operator Achievement Award**

1,000 2-way contacts with any station on any satellite
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Mark Rosenberg, AD4KS
331 S. Yates
Memphis, TN 38120

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**VHF/UHF Society Century Club Award (VUCC) with Satellite Endorsement**

1 Satellite Contact with any station in 100 Different Grid Squares.
Endorsements for each additional 25 grid squares.

**Worked All Continents Award (WAC) with Satellite Endorsement**

1 Satellite Contact with any station on each of the 8 continents.

**Worked All States Award (WAS) with Satellite Endorsement**

1 Satellite Contact with any station in each of the 50 states.

**DXCC Award with Satellite Endorsement**

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Other awards are available through other organizations. This list represents the major awards.

Prepared by Bruce Paige, KB5ZRV

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# Heard on The Downlink

*by John Hansen, WAØPTV*

### How Long Will P3D Last?

I remember a couple of years ago at Dayton, Tom Clark was doing a presentation on the upcoming P3D project when someone in the audience asked "How long will it last?" Tom pointed out that this depended entirely on what the cause of death would be. AO-13 for example would die because it will prematurely re-enter the earth's atmosphere. Now that the mechanism by which this will occur is understood, it can presumably be avoided in the case of P3D. Barring catastrophic failure, Tom concluded that the most likely cause of death for P3D would be the eventual failure of the satellite's battery.

It is with this background in mind that it is worth considering recent developments in battery acquisition for P3D. Until a few months ago, it had been planned that P3D would use a battery with a 4 to 6 year estimated lifetime. However, last Spring the project was offered a specially-built battery with a guaranteed life of 10 to 12 years. One catch though... it required an immediate expenditure of some $100,000. As it turned out AMSAT-UK rushed to the rescue and raised the needed funds. Bravo! guys. Jolly good show!

### Saving Money on WiSP

You may have read the article in the last issue of this Journal concerning WiSP. The groundstation software for use with most of the digital satellites has been in beta testing for many months now. With the conclusion of the beta testing period, the price of registering the software will rise. Currently, the suggested registration contribution for this program is $30. Beginning November 1, registration only will rise to $40 for AMSAT members and $50 for non-members. If you need the disk as well (that is, you did not obtain the program from another user or one of the BBS's or internet sites where it is posted) the cost will be $50 for members and $60 for non-members. Please note that these price changes are being announced now, but not implemented until November 1 to give everyone who wishes and opportunity to jump in at the beta-test registration price.

### Yaesu Rotator Problem

Last year at this time I reported on my problem with the Yaesu 5400B rotator and its solution. In the process of repairing my unit I discovered that as rotators go, this is one of the easier ones to tear apart and fix. I was interested to receive a note from Dave Kaplan, WB0WNX concerning a somewhat stranger problem he had with his 5400. It seems Dave ran into a fairly serious problem with the azimuth indicator on his rotator system. This was not due to the rotator simply slipping "off-


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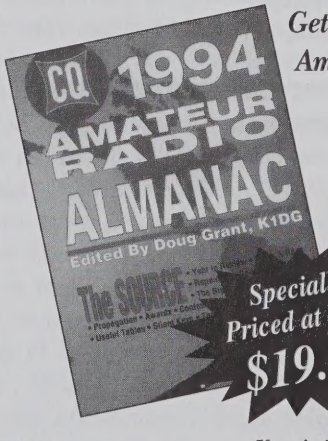


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course" because the degree of off-pointing differed depending upon which direction the antenna was pointed. For example, if the indicator said "North" the antenna was actually pointed west (off by 90 degrees), but if the indicator said "East" the antenna was actually pointed 315 degrees (off by 135 degrees).

Dave went through a rather extended trouble shooting phase with this problem. The bottom line was that a 6 volt voltage regulator (Q2 in the control box) had failed and was allowing a greater voltage than this to pass. Thus, the 500 ohm pot in the rotator itself no longer produced the indication on the meter on the control box that one would expect. Replacing the voltage regulator cured the problem.

### Notes from HQ

Martha at HQ asked me to remind you of a couple of things. First, the AMSAT-NA annual financial statement and auditor's report is now ready for your review. If you would like to receive a copy send a large self addressed, stamped envelope with 98 cents postage to the HQ address on page 3 of this issue.

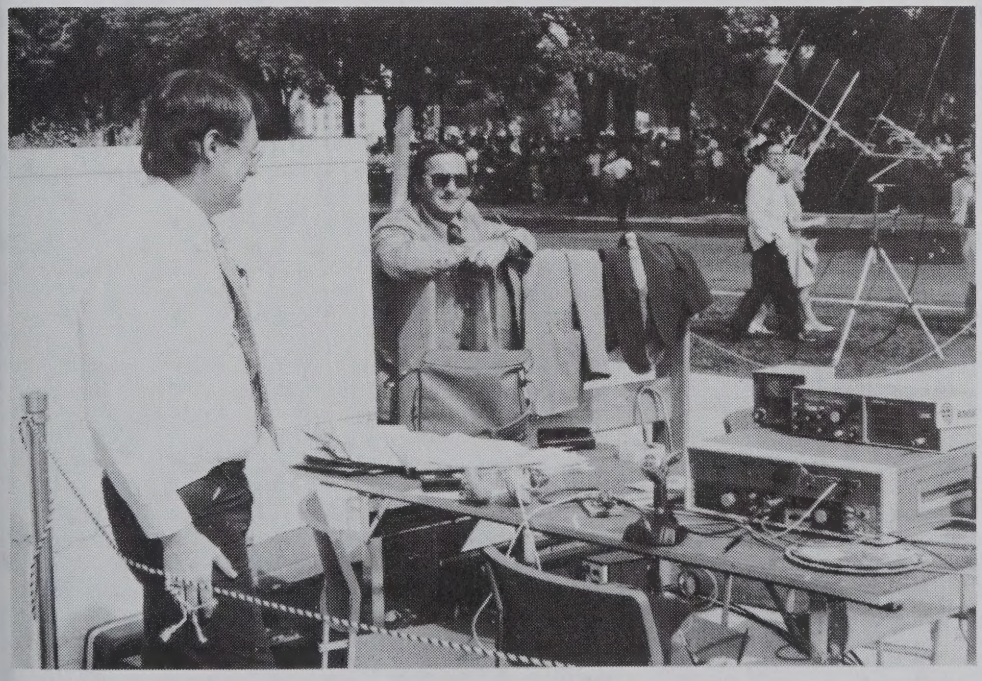
Secondly, if you are an AMSAT-NA life member living outside the United States you are (like all life members) receiving *The AMSAT Journal* without additional payment. However, because of the high cost of air mail, life members outside the U.S. receive it by surface mail rather than air mail. If you would like to receive the *Journal* by air, you may do so by paying the extra postage associated with air mail delivery. Currently, this amounts to $15 per year. If you would like to take advantage of this option, simply send your payment to AMSAT-NA HQ.

### Election Results

The results of the annual election for the AMSAT-NA Board of Directors have now been tallied. A total of 1548 members cast ballots in this year's election and the outcome was as follows:

| | |
|---|---|
| Tom Clark | 1199 |
| Andy MacAllister | 837 |
| Keith Baker | 781 |
| Bob Myers | 614 |
| Lou McFadden | 573 |
| John Hansen | 505 |

The top three vote-getters receive seats on the BOD, while the next two highest totals are the alternates for the coming year.



**From the 25th Anniversary archives: Tom Clark, W3IWI and Roy Rosner, K4YV represent AMSAT at the dedication of the new Air and Space Museum in Washington (1972).**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# DSP-93

# It's not too late to get YOURS!

**Although the first production of DSP-93 kits has been filled, TAPR and AMSAT are currently taking orders for the second batch of kits to be shipped in March, 1995.**

### DSP-93 Design

The DSP-93 is designed to provide radio amateurs Digital Signal Processing in a stand-alone low-cost design. Not just limited to one mode, the DSP-93 can support data, audio, and video modes with the proper software.

The basic system includes a DSP engine board and a radio/computer interface board. The DSP Engine, bottom board, contains the TMS320C25 DSP, 32K by 16 bits of program and data memory - upgradable to 64K, the clock circuitry (40Mhz) and some programmable array logic for system I/O. The Radio/Computer Interface Board, top board, contains two eight pin female mini-DIN connectors for radio interfacing. The Texas Instruments TLC32044 Analog I/O chip is used. This board also communicates to your computer at speeds up to 19.2K baud using a serial connection.

### Software

The initial offering of the DSP-93 contains the following software: 1200 baud AFSK, 300 baud AFSK, 1200 PSK, 9600 FSK terrestrial, 9600 FSK full-duplex for satellite operations, APT, HF modem (RTTY, AMTOR, PCTOR), and audio filters. User interface software for PC and Mac is available. Since the DSP-93 is an open architecture, it is hoped that as more amateurs get their units, more software will be developed and distributed.

### Code Development

A low cost shareware assembler is available for code development. To make this project a success, more people are needed who want to learn about developing DSP applications, networking, and converting from the real linear world to the digital world. Some of the areas for development might include: new modulation techniques, speech synthesis, filters, spectrum analyzers, and many more applications you will think of. If you choose to work on the hardware aspects of this project, the modular approach should allow you to convert to other DSP chips or Analog I/O chips or to add additional capability.

### Future Options

• High Speed Radio Interface board is a second radio interface board with higher speed analog I/O chips. The A/D chip is capable of 200K samples per second with eighteen bits of resolution and the D/A chip can attain 300K updates per second with eighteen bits accuracy.

• Network Interface board is intended to support higher speed modes which require moving large amounts of data to the computer faster than a serial port can handle.

• TNC Interface board can be placed inside the DSP-93 for the decoding of HDLC frames for packet radio applications.

### Project Team

Any of the project members welcome questions about their work and involvement. If you know someone on the team, please ask them about their unit and how it operates.

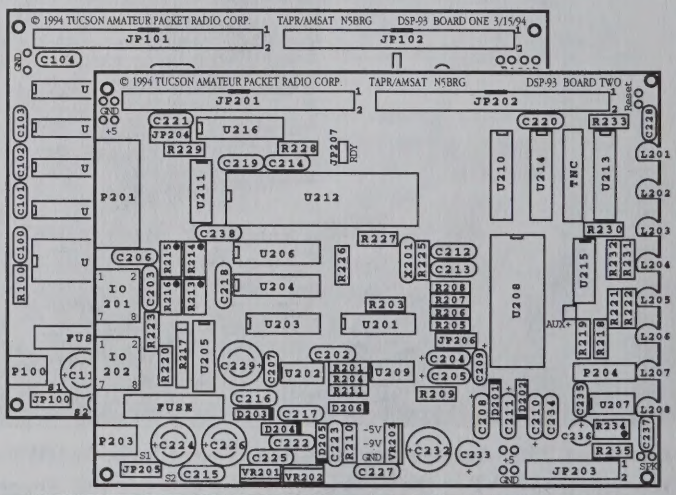
### Ordering your DSP-93 Kit

The DSP-93 sells for $430 as a complete kit, including enclosure and power supply. For those not wanting to build a kit, there are several preassembled DSP units on the market today. If you live in a country that does not use 110v 60Hz AC, the price will be $420, and the unit will ship without the 9V AC wall transformer. (Please specifiy this in your order).

Note: Assembly of TAPR kits can be complex, depending on the experience of the builder. Though not any more difficult than the PSK TAPR kit, the DSP-93 requires prior kit-building experience and basic knowledge of electronics to successfully go from a kit to a finished, working unit. For some data applications, modification must be made to your radio.

DSP-93 kits are provided in batches as the demand warrants doing kits. Orders for the next batch, to be shipped in March, are now being taken.

**DSP-93 orders for the March purchase will be taken until December 31st, 1994.**

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